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## ANNUAL REPORT OF THE ISTHMIAN CANAL COMMISSION TO THE SECRETARY OF WAR.

The report of the Isthmian Canal Commission for the year ending June 30, 1907, was made public at Washington on Nov. 27, nearly five months after the close of the fiscal year. We reprint below those portions of the report of most interest to our readers and reproduce herewith some recent photographs taken on the Isthmus and furnished us by the Commission. It is pointed out at the opening of the report that most of the work done during the fiscal year covered was done under direction of Messrs. Shonts and Stevens, the engineers at present in charge holding office only for the last three months of the fiscal year.

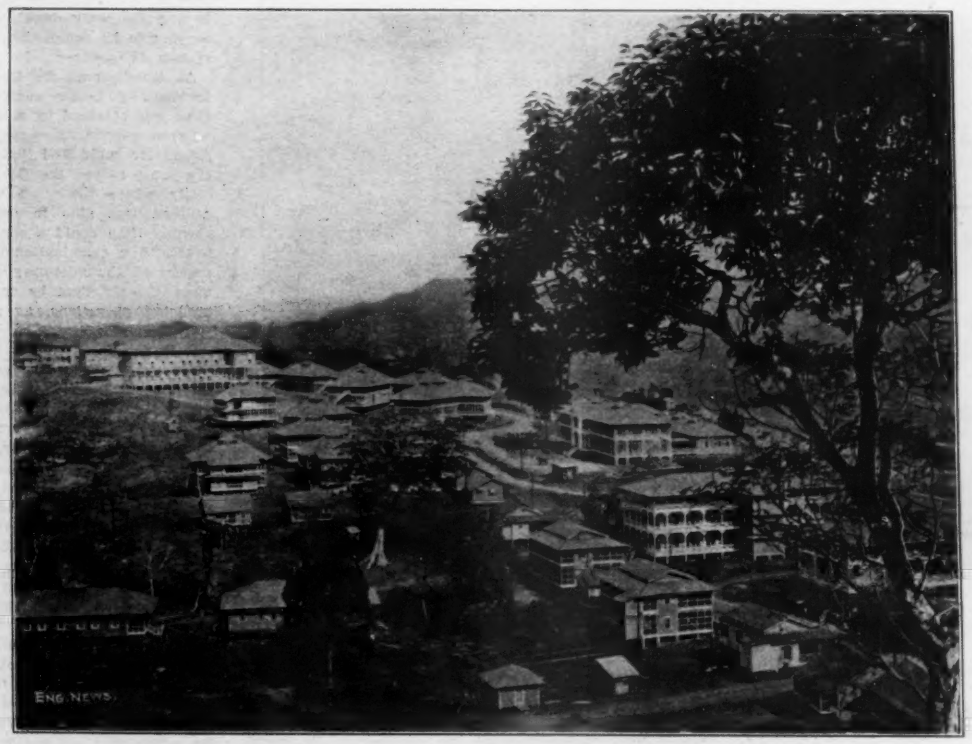
Culebra, Canal Zone,
October 17, 1907.

Sir: I have the honor to submit, on behalf of the Isthmian Canal Commission, its annual report for the fiscal year ending June 30, 1907.

### ORGANIZATION OF THE COMMISSION.

At the close of the previous fiscal year the Commission consisted of six members. During the present fiscal year the entire personnel was changed, brought about by the transfer of Governor E. Magoon, on September 25, to administer affairs in Cuba, by the acceptance of the resignations of Mr. Theo. P. Shonts, chairman, effective March 4, 1907; of Gen. Peter C. Hains, Maj. B. M. Harrod, and Rear-Admiral Mordecai T. Endicott, effective March 16, 1907, and, finally, of Mr. John F. Stevens, chairman and chief engineer, on April 1. To the vacancies thus created were assigned three officers of the Corps of Engineers, U. S. A.; the Chief of Bureau of Yards and Docks, U. S. N.; an officer of the Medical Corps, U. S. A. and two civilians. The two important changes resulted from a combination of the positions of chairman and chief engineer on March 4, and from the requirement that the Commissioners take station on the Isthmus, where they can be in direct touch with the work committed to their charge. The new Commission assumed its duties on April 1, 1907.

In order to utilize the services of the engineer members of the Commission in construction work and to secure a closer supervision of the details of the work, then rapidly expanding, through a head directly responsible to the chairman and chief engineer, the Department of Construction and Engineering was subdivided into departments, each in charge of a member of the Commission, as follows; Department of excavation and dredging, Department of lock and dam construction, Department of municipal engineering, motive power and machinery, and building construction.




VIEW OF CULEBRA VILLAGE FROM THE RESERVOIR.

(Administration Building at the left, Hotel at the right, Y. M. C. A. Club House in the Center.)

### EXCAVATION AND DREDGING.

This department of construction embraces the Culebra division, extending from the Chagres River to Pedro Miguel, the Chagres division, embraced between deep water in Lake Gatun and the Chagres River, the Colon dredging division, extending from Gatun to deep water in the Atlantic, and the La Boca dredging division, taking in all excavation between the La Boca locks and deep water of the Pacific.

CULEBRA DIVISION.—The Culebra division is practically 10 miles in length, and early in the wet season it was recognized that general supervision of all the steam shovels or all the trains of the entire division under one supervisor or superintendent was not productive of the best results in fixing responsibility in case any part of the work was not progressing satisfactorily, consequently a slight change in organization was effected on July 1. This consisted in subdividing the division into five construction districts, each under charge of a superintendent of construction, who is held responsible for the work in his district. Better results have followed with less friction.

Since the close of the fiscal year the monthly output improved over the early months of the wet season, as indicated by the following table:

| Month. 1907. | Number of working days. | Daily average number of shovels at work. | Output. Cu. yds. |
|---|---|---|---|
| July | 26 | 43.38 | 770,570 |
| August | 27 | 39.70 | 786,866 |
| September | 24 | 38.50 | 753,468 |

The greatest difficulty found in maintaining the output thus far during the rainy season is due to the dumps; the material being loose sinks under train loads after being wetted by the heavy rains, causing considerable delay if not entirely preventing the use of the dump until it has dried out.

CHAGRES DIVISION.—On this division only preparatory work was done during the year. The Chagres River crosses the center line of the canal 23 times within the limits of the division. Though the amount of work to be done is relatively not large, the conditions are such as to militate against rapid progress. Since the close of the fiscal year work has been commenced and steam shovels diverted from the Culebra division until others under contract are delivered.

COLON DREDGING DIVISION.—This division consists of the Mindi and Colon districts. In the former about 700,000 cu. yds. of material in the vicinity of Mindi Hills will be removed by steam shovels, this method being more economical since the borings made during the fiscal year indicate that a large percentage of rock is found in this locality; the remainder will be dredged.

The excavation by dredges during the fiscal year amounted to 1,112,321 cu. yds., place measurement, of which 43,602 cu. yds. were rock.

LA BOCA DREDGING DIVISION.—The dredging fleet for this division consisted of one old French ladder dredge and one 5-yd. dipper dredge. A second French ladder dredge was undergoing repairs and was put in operation after the close of the fiscal year. A seagoing dredge similar in type to the suction dredge for the Colon end is under contract and when finished will proceed under its own steam by way of Cape Horn to Panama. The ladder dredges and dipper dredges were served by seven French self-propelling dump barges, and a contract was made for three steel hopper barges to be used for the same purpose.

During the past fiscal year 1,235,807 cu. yds. of material were dredged from the division.

### LOCKS AND DAMS.

This department of construction embraces the Gatun locks and dam, the locks and dam at Pedro Miguel, the locks and dams at La Boca, meteorology and river hydraulics.

The locks are in pairs, each, as now proposed, with usable lengths of 1,000 ft. and widths of 100 ft. The adopted project contemplates a flight of three locks at Gatun, a flight of two at La Boca, and one lift at Pedro Miguel.

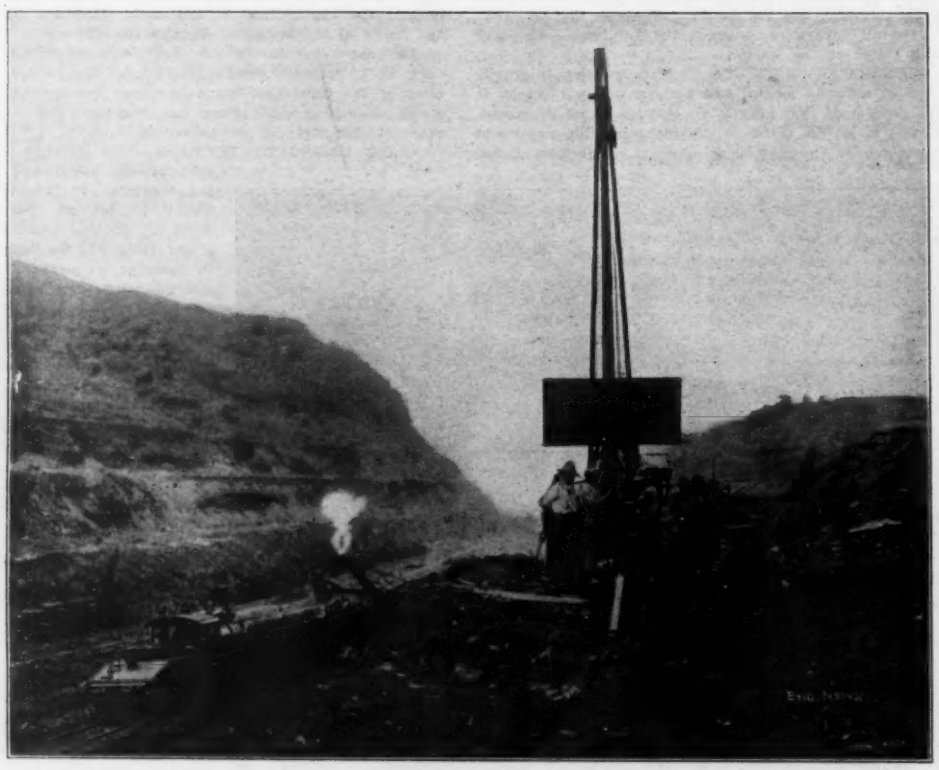
Prior and subsequent to the adoption by Congress of the 85-ft. level canal in June, 1906, borings were made to determine the character of the foundations at the various lock sites. The classification of the data so obtained was recorded in such a way as to cause considerable adverse comment, questioning the suitability of the material for the purpose. To actually develop the character of the foundations on which the locks

are to rest, five test pits each 6 ft. × 8 ft. were sunk to the depths of the lock walls at Gatun, two at Pedro Miguel, and one at the spillway in Gatun dam. The outcropping of trap rock at La Boca, which borings showed extends to proper depths, rendered such examinations of the foundations for these locks unnecessary. On the completion of the test pits a Board of Consulting Engineers, consisting of Alfred Noble, Frederick P. Stearns, and John R. Freeman, made a personal examination of the material, and under date of May 2, 1907, reported as follows:

We beg to record that we found that all of the locks of the dimensions now proposed will rest upon rock of such a character that should furnish a safe and stable foundation.

Since then careful borings have been continued over the entire area in order to secure a contoured plat of the rock surface with a view to the most economical adjustment of the locks to the site.

Subsequent to the adoption of the project, studies were begun of locks, gates, and sluiceways. From these studies the Commission finally decided upon the method of filling and emptying the locks and the number and type of gates. The gates are in duplicate and of the miter type, except that the rolling gate similar to that now in use on the Ohio River will be substituted for the duplicate set at the lower end of each summit-level lock. In addition there will be provided an auxiliary pair of gates at the lower end of each flight for use



VIEW IN CULEBRA CUT, HALF A MILE NORTH OF "CONTRACTOR'S HILL." A CHURN DRILL AT WORK.

as cofferdams in case it may be necessary to pump out the locks, and it has been determined tentatively to adopt a swing-bridge type of dam for emergency use. The designs for the locks and gates are progressing satisfactorily.

GATUN LOCKS AND DAM.—Excavation of the lock site by steam shovels was begun in September, and by the end of March four shovels were at work, and a total of 484,362 cu. yds., place measurement, of earth and rock were removed during the year.

About 573 acres of the site to be occupied by the dam were cleared of timber, and a pile trestle was partially driven along the 30-ft. contour on the upstream toe of the dam for the purpose of depositing rock from Bas Obispo as an integral part of the dam. Contracts were entered into for two 20-inch pipe line suction dredges for construction use on the lower portion of the dam.

The cross section of the dam has been slightly changed and the upstream slope made more gradual than that originally proposed.

A topographical survey was made of the basin of the lake up to the 100-ft. contour, and all the saddles in the hills were carefully examined to ascertain the nature of the material composing them. The survey was practically completed at the close of the fiscal year, from which the area of the lake is determined to be 164.23 sq. miles.

MUNICIPAL ENGINEERING, MOTIVE POWER AND MACHINERY, AND BUILDING CONSTRUCTION.

DIVISION OF MUNICIPAL ENGINEERING.—The work performed by this division during the fiscal year included the paving of streets and construction of water-works and sewer systems in the cities of Panama and Colon, paving, roadmaking, grading, construction of water-works and sewer systems, and miscellaneous work of a similar nature in the Canal Zone, necessitating an expenditure of $1,741,953, divided about equally between work in the cities of Colon and Panama and work in the Canal Zone.

The cost of work done in the cities of Colon and Panama will be reimbursed to the United States.

The average daily force carried during the year was 2,593 employees, both gold and silver.

DIVISION OF MOTIVE POWER AND MACHINERY.—The work of this division embraced the erection and preparation for service of machinery necessary in canal construction and its maintenance in good repair; the installation and operation of air-compressor plants; the performance of work in connection with electrical installations, and the manufacture and repair work for other divisions. During the year 2,479 employees were carried on the rolls and expenditures made to the amount of $6,360,496.56.

To date the following machinery has been erected and made ready for service: 63 steam shovels, 284 locomotives, 2,706 dump cars, 18 unloaders, 13 bank spreaders, 33 unloading plows, 3 track shifters, and 7 pile drivers.

BUILDING CONSTRUCTION DIVISION.—The work of this division consisted in the construction of buildings for the different departments and divisions of the Commission.

A total of 767 new buildings were constructed covered by this report, and on June 30, 1907, there were on hand 2,919 buildings of all classes.

The average force employed was 3,570 men, and in the work outlined above $4,357,587.57 were spent. The largest single item of expenditures was for quarters for gold employees, amounting to $1,432,415.51. The next largest item was for the construction of silver employees' quarters, amounting to $482,502.88. For the construction of buildings for hospital purposes there were expended $315,196.57 and for supervision and clerical force $193,763.73. These figures for construction work include both labor and material.

DIVISION OF MATERIAL AND SUPPLIES.—During the year material was received by purchase to the value of $9,500,000, of which over 90% covers purchases made in the United States. This has entailed the handling of 37 full cargoes of material and partial cargoes from about 150 vessels. A large amount of old French material, consisting of boilers, pumps, Decauville track, cars, locomotives, cranes, and other material, has been repaired and placed in service. About 11,000 tons of this old French material were disposed of to [illegible] in the United States as scrap iron.

In addition to the work of handling all supplies for the Commission this division is charged with the [illegible] and operation of corrals and equipment used for [illegible] transportation on the Isthmus. Over 600 horses and mules, with the necessary wagons, carts, [illegible] and ambulances, are in this service. In this connection it is interesting to note that the cost per month per team to the Commission for teams actually working, including all charges for labor, forage, and miscellaneous items, as well as expense of sick teams, was about $110. A proposal was received recently by the Commission from a contractor in the United States, who has had considerable experience in similar work in Central America, to do all land transportation at the rate of $450 per month per team, or over four times what it is costing the Commission at the present time.

Twelve hundred and eighty-nine employees were carried on the rolls of this division, and expenditures on account of its operation amounted to $755,321.89.

CONTRACT VERSUS HIRED LABOR.

Under date of Oct. 9, 1906, sealed proposals were invited for the complete construction of the canal in accordance with the approved plans, bids to be opened on Jan. 12, 1907. As none of the bids received appeared to be entirely satisfactory, they were rejected, and the work was continued in the same manner as it was progressing at the time that the invitation was issued.

There is no question that in the majority of cases in the United States work is contracted because it can be done cheaper by that method than any other. This is generally due to the fact that the contractor has on hand a construction plant which can be more cheaply hired than purchased anew. Where, in any particular case, either from the nature of the work or its location, the contractor must purchase machinery and appliances which, so far as he can foresee, will be practically useless in the completion of the work, or where the party having the work done can make use of the plant subsequent to its completion, the advantages of the contract system disappear.

As illustrative, the Government secured cheaper and incidentally better concrete work in its fortifications than was obtained by contract. The batteries are heavy concrete constructions requiring machinery for which the contractor could find little, if any, subsequent use. For the same reason the Government, in many cases, especially where the work was removed from commercial centers, was able to construct locks and dams more cheaply than could a contractor. In some instances, to overcome a combination of contractors, the Government purchased the necessary plant and accomplished results more cheaply than by contract; this is notably true in dredging operations, as recent legislation on the subject clearly indicates.

It is not uncommon in the execution of comparatively large projects that the contractors have failed and the Government carried successfully to completion, by hired labor, the work undertaken by the contractor. Notable instances of the Government successfully completing work are the State, War, and Navy Department building and the Congressional Library, Washington, D. C.

Omitting profits derived from subsistence and general stores, and assuming the hours of labor the same in both cases, it stands to reason that the Government, when warranted in making the necessary outlay for plant, can do work cheaper than a contractor, for no question of profits enters into consideration.

The question of Government work versus contract in connection with the Panama Canal has been discussed, and a conclusion reached in favor of the latter method because of certain stated advantages that are claimed to result. To those familiar with river and harbor improvements, erection of public buildings, lighthouses, etc., and with contracts under the Government, the advantages set forth are not so apparent or real.

It is claimed that contractors have under their control and at their disposal trained labor forces, and that by a combination of such forces, through an association of contractors, team work will result, thereby accomplishing the desired end more quickly. As a matter of fact, conditions seldom enable a contractor to maintain intact his entire organization on one piece of work for transfer to another; the completion of a job means the disbanding of the force, and though new work may bring to him some of his old men, a new organization must in each case be perfected.

The Panama Canal presents a piece of work unprecedented in magnitude, which must be done under conditions entirely different from similar classes of work in the United States. The work naturally divides itself into dredging, dry excavation, the construction of the locks and dams, and the construction of the new Panama Railroad. There is no contractor or syndicate of contractors that by any combination could bring to the Isthmus an organization ready for team work on any of these units. While it is possible for several contractors to combine forces, assuming that a sufficient number of men can be gotten together in that way, there still remains the necessity for whipping this force into shape

in order to secure an organization that will produce the team work so advantageous in the accomplishment of results.

From the United States the supply of labor is the same whether the work be done by contract or by the Government, and the character of the labor must be the same. So long as work is plentiful, the dread of the Tropics will deter men from seeking work here in preference, and this is equally applicable to the contractor and the Government. An adequate supply of labor from the United States is not possible, and recourse must be had to securing it abroad. The records here show that no contractor can even attempt to recruit labor in the West Indies, and that great opposition will develop to any recruiting by authorized agents of the Commission if the labor procured is turned over to contractors. These island governments can not be blamed for their hostility toward the latter because of their experience under the French, which left an indelible impression throughout the West Indies. A representative of the Italian Government has recommended to the authorities that Italian labor be permitted here for employment under the Commission, but he is not favorably inclined to the control of such labor being vested with a contractor.

It is true that in some cases the contractor may have an acquaintance which will enable him to secure suitable men more easily than a Government agent, and, again, he may bring to a work a greater experience, but so far as the most important parts of the Panama Canal work are concerned, this advantage is not apparent. In any case the knowledge of the specialist in the particular work that is to be done is the element that will accomplish the most satisfactory results, and, so far as dredging and lock and dam construction are concerned, the Government's experience has been, if not greater, at least as extensive as that of any contractor or association of contractors that can be secured in the United States.

For these units of the work the Government's acquaintance is equally extensive, and experienced men can be drawn from the engineering force of the Government. These three classes of work form the most important parts of the Panama Canal, and in their prosecution the Government has the advantage. So far as relates to excavation in the dry by steam shovel and cars the advantage ordinarily would be with the contractors, yet the Government has secured and maintained an organization on the Isthmus that can not be surpassed by any contractor, and, it is claimed, has perfected this organization in as short a time as, under the circumstances, could have been done by any association of contractors.

When the Government does work in the United States, the wage scale is determined by the amount paid for the same class of labor in the immediate vicinity; there is no pressure brought to bear on higher authority for any increase over the salaries or amounts offered, and strikes are unknown. It is true that conditions on the Isthmus are such that demands for increase in pay are frequent, and that to accomplish what was denied by those immediately in charge of the work recourse has been had to higher authority.

Conditions on the Isthmus are peculiar. It is contended, apparently on reasonable grounds, that service in the Tropics saps the energy, and that a man is incapable, after a time, of performing the same amount of work that he would be able to accomplish had he spent the same period in a cooler climate. This creates a desire to accumulate sufficient means to avoid the necessity of relatively harder work on the return to the United States, and is a question that a contractor would be obliged to face as well as the United States. In some respects the Government is in a position to handle the situation more satisfactorily than a contractor, as was plainly shown by the trouble with the steam-shovel men in May last.

The wage scale on the Isthmus is practically adopted and a contractor would be obliged to maintain it. Under the recent decision that all questions of pay are to be left with the Commission, this body is placed on as secure a basis relative to the constant demands for an increase as any association of contractors.

Experience has shown that continuity of construction is more apt to result in cases where the Government undertakes the task than when it is turned over to contractors. This can be easily verified by an examination of the records (the number of failing contractors) to be found in the office of the Chief of Engineers. For all work done by hired labor continuity of work is merely a question of continuity of appropriations. It is true that continuity may be equally insured by turning the Panama Canal work over to contractors, if the contract is so drawn that practically all risks are assumed by the Government, but why this should be done, at a considerable increase in cost, is not apparent.

To anyone who has had experience with contracts on Government work, the claim that letting a piece of work by contract is a reasonable assurance that it will be completed in a definite time is utterly untenable. On public works, including public buildings, it may safely be said that in the majority of cases the time limit is exceeded. An examination of the contracts for material to be supplied the Isthmian Canal, so far as the time limits proposed by the contracts are concerned, will clearly show that there is no assurance of completion in a definite time of any contract, even though the contractors themselves, when fully cognizant of all the conditions surrounding the work, fix the time for the completion or delivery. It certainly can not be supposed, therefore, that in an enervating climate, like that on the Isthmus, and with labor below that in the United States in efficiency, this time-failing record for contract work would be changed.

Reasonable definiteness in cost is usually obtained by contract, when based on unit prices and when all conditions of the work are fully known in advance, yet these unit prices are as a rule higher than would be the cost to the Government should the latter possess the necessary plant. It is true that the contract which was proposed for the construction of the canal provided for the determination of time and cost by a board of engineers, but the conclusions on these points could be upset should conditions be found or met with unforeseen by that board. Experience on all works, even those based on more definite data than can be presented to contractors for the Isthmian Canal work, shows that the unexpected is always happening, and this seems especially true of the work here.

There is no question that there are a number of people who will always believe and contend that any piece of work done by the Government could have been done as well and more cheaply if undertaken by contract, but an examination of the records will generally disprove such a contention. On the other hand, there is an equally large class who will contend to the contrary and claim, after the completion of the work, that the reverse is true.

Work heretofore has been conducted on a nonpartisan basis. The thinking class of American people fully realize the necessity for the Panama Canal and its early completion, and it is generally realized that this can be accomplished only by the application of business and nonpartisan methods. This has generally been the case with all Government work wherever undertaken, and the fact that the continuation of this policy may not continue along the same lines is hardly an argument strong enough to weigh in favor of contract work.

While it has been noted that contractors can usually do work cheaper because of plant already on hand, thereby saving the cost of new machinery, and because of greater familiarity with the class of work on which they are engaged, there are at times additional ways for securing the same results, namely, (a) by paying lower wages, (b) by working their men longer hours, (c) by requiring a greater amount of work per hour from the men, (d) by giving them less expensive rations and quarters, in case employees are fed and quartered.

On the Panama Canal a contractor can not anticipate profits from any of these sources. The work already done and in progress has fixed the wage scale, and a contractor would be unable to retain labor that might be turned over to him, nor could he secure additional men at less salary than already paid by the Commission.

The Government is now working foreign labor as many hours per day as is practicable in this climate, so the contractor could gain nothing more than the Government has already acquired. So far as American labor is concerned, the eight-hour law is applicable, and so long as it remains in force it must be as binding on the contractor as on the Government.

It is questioned whether he could get more work out of the laborers on the Isthmus than they now perform for the Commission. This is a question dependent entirely upon the character of foremen employed, and he would have exactly the same class of men in this position, since most of the foremen now employed have previously been with contractors, and therefore have had their principal training on contract work. Moreover, the pace set by the laborers under the Commission would fix the rate for the contractor.

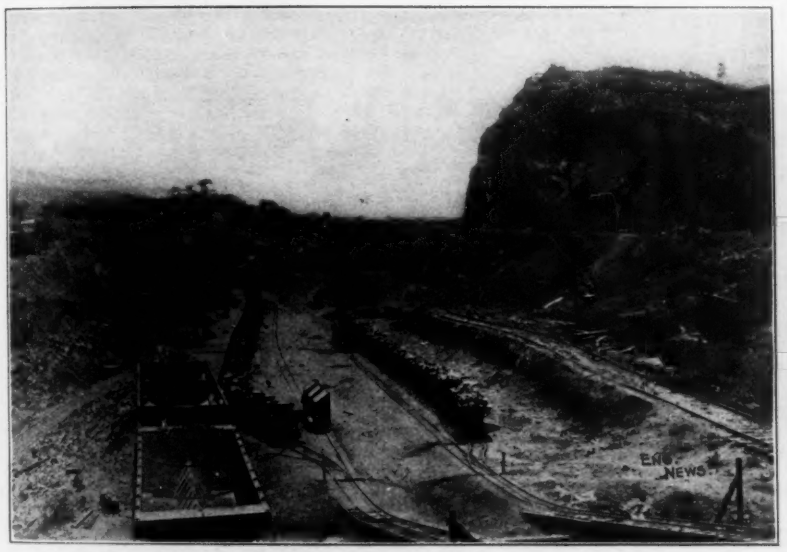
Were all the work turned over to one contractor, or an association of contractors, the Commission would be obliged to maintain a supervisory force, and the feeding and quartering of these employees would determine the demands that the contractor's men would make upon him for accommodations. Moreover, a number of the dwellings that are now occupied by Commission employees would be turned over for occupancy by contractor's men, and any additional force would expect the same accommodations. Trouble would result, therefore, in case the contractor fed his employees on less expensive rations or quartered them less comfortably than the Commission; no saving could be made, and the Government would be obliged to foot the bills.

The Panama Canal work is naturally divided into—

(1) Excavation in the dry by steam shovels, including all of the Culebra division and part of the Chagres division. The construction of drainage and diversion channels would come under this heading.

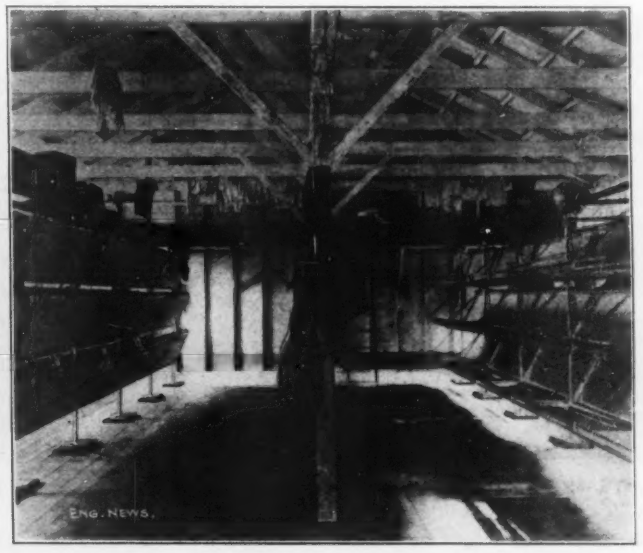
(2) Excavation by dredges on the Colon and La Boca divisions and on part of the Chagres division.

(3) The construction of the dams.




PREPARING FOR A BIG BLAST NEAR BAS OBISPO.

(Blast fired, Sept. 10, 1907. Four drill holes were put down with well drills to a depth of 78 ft. and charged with 9,600 lbs. of black powder. The face of the cliff on the right was thrown down and nearly 30,000 cu. yds. of rock was displaced.)




SLEEPING QUARTERS FOR EUROPEAN LABORERS.

(4) The construction of the new Panama Railroad.

(5) The construction of the terminal facilities, harbor basins, and breakwaters, if any.

(6) The construction of locks, gates, and spillways.

The excavation of the Culebra division has already been undertaken by hired labor; practically all of the plant required for this work has been secured and paid for; a complete and thoroughly efficient organization for the same has been built up, and the Government is not hampered in any way in procuring the necessary labor for filling vacancies that arise. In the organization that has been perfected the higher grade men were formerly employed by contracting firms, and some of the number have been successful contractors themselves. The conduct of this work, therefore, has been along the lines usually followed by contractors. Under the circumstances no advantage would accrue to the United States by letting this piece of work to contractors, but on the contrary there would be not only additional expense, but a feeling of unrest and dissatisfaction engendered among the present employees materially affecting efficiency. Under existing conditions, therefore, contract work can not be recommended for the Culebra division.

The Government has on hand, or under contract, all the dredges that will be needed for excavating such parts of the canal prism as can be most economically performed by this class of machinery. Experience in the United States has demonstrated that with such a plant in its possession no contractor or association of contractors can do the work as economically as can the Government. The Government agents are as familiar with this class of work as the contractors, and the necessary dredge crews can be obtained without difficulty. So far, therefore, as dredging is concerned, the Government should do the work and contracts for the same can not be recommended.

The great problem in the construction of that portion of the canal included in the Culebra division is the disposal of the excavated material. In the main this has been disposed of at various localities favorably situated with regard to the cut. The systematic performance of the work and the necessity for additional material in completing other parts of the work have made it necessary to arrange for such a disposition in the future as will be most beneficial to the work in its entirety. The efficiency of the dams depends upon their having sufficient weight and tightness to impound the water without leakage and without danger to the stability of the structures. The weighty material, or rock, is to be furnished in each instance by material from the Culebra cut and the tightness is to be secured by the selection of suitable material to be obtained from the products of dredging. In other words the construction of the dams is so intimately connected, both with the excavation of the Culebra cut and the dredging, that if these two can be most economically and advantageously done by the Government rather than by contract it naturally follows that the method adopted for the construction of the dams must be the same, namely, by hired labor under Government supervision and not by contract.

The survey of relocation for the Panama Railroad has been completed and it has been necessary to undertake the construction of the railroad in order to permit the removal of the present bed in the vicinity of Gatun, so that the construction of the dam at that point may be begun. The construction of the new line requires, among other things, about 1,600,000 cu. yds. of excavation and about 12,000,000 cu. yds. of embankment. The excess of embankment over excavation, about 10,000,000 cu. yds., is to be supplied largely, if not entirely, from material excavated from the canal prism, the embankments forming dumps for the material trains. Steps have already been taken for the development of dumps which will result in the construction of a part of the new roadbed at Miraflores, Pedro Miguel, Gamboa and Gatun, and plans have been prepared and proposals invited for a bridge across the Chagres at Gamboa. With excavation in the Culebra division to be done by hired labor under Government supervision, with the material therefrom to be used in the construction of the Panama Railroad, the intimate relation between the two necessitates the adoption of the same method of construction, namely, hired labor under Government supervision, in the construction of the new Panama Railroad.

The regulating works and spillways of the Gatun and La Boca dams are so dependent upon and intimately connected with the construction of the dams that whichever method is adopted for the latter must be made applicable to the regulating works and spillways, in order to avoid friction and difficulties that would result in case part were done by the Government and part by a contractor.

The Panama Railroad must be maintained and operated as a commercial line, and it must be utilized also for construction purposes in connection with the Culebra cut, the reconstruction of the railroad, the construction of the dams, and in addition it must transport all materials entering into the construction of the Pedro Miguel locks.

The difficulties that would result from a joint use of the Panama Railroad by a contractor and the Government at the Pedro Miguel locks disappear, however, for the locks at Gatun and La Boca, since both are accessible by water. Sand can be procured along the shores of the Pacific, and a suitable quality in sufficient quantity can also be obtained on the Atlantic shore of the Isthmus.

The success of the lock construction depends largely upon the quality of cement used, and there is no question that the Government should furnish all the cement. No contractor, or association of contractors, possesses the necessary plant for handling the enormous quantities of concrete required for these structures. Subsequent to the construction of the locks the contractor could have no further use for the machinery installed, even if the payment of freight for its return to the States were warranted. If the contractor furnishes the plant, the Government must pay for it in its entirety and in addition pay interest on the amount expended for its purchase. This plant can be procured more cheaply by the Government than by a contractor. As previously explained, if the Government furnishes the plant, the advantage of the contract method disappears. The contractor will have greater difficulty in securing the common labor needed than will the United States. The engineering force of the Government that has in the past few years been employed in the construction of such large quantities of concrete in various forms in the United States can be drawn upon to furnish the skilled personnel necessary for concrete work here. The acquaintance with competent men, for this class of work, is more extended on the part of the Government than on the part of the contractor.

These considerations lead to the conclusion that the locks can be more economically and advantageously constructed by the Government than by a contractor or association of contractors.

The gates and operating machinery can, it is believed, best be constructed by contract at the proper time.

The foregoing conclusions do not cover the proposed work on the Chagres division or the terminal facilities, harbor basins, and breakwaters, as the survey for the development of the amount of work and character of material involved in the Chagres division has not yet been completed, nor have the final plans for terminal facilities, etc., been finished.

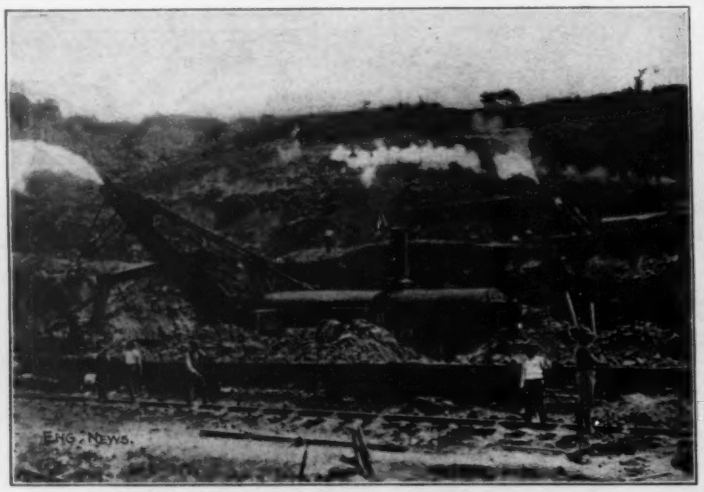
No account has been taken of the question of sanitation, one very important to the successful prosecution and completion of work on the canal. Proper sanitation can be maintained more easily and satisfactorily with the Government in supreme control of the work than with a contractor, and this adds an additional argument in favor of the Government doing the work itself.

The relative advantages of the contract system versus hired labor under Government supervision in the construction of the Panama Canal are very different today from what they were two years ago, and were different then from what they were when the work was first undertaken. To one familiar with conditions on the Isthmus there can be no doubt at this stage of the work as to the advisability of continuing it by hired labor.

It is estimated that 80% of the entire plant needed for the construction of the canal has been purchased or contracted for. Machine shops have been erected and equipped for making all needed repairs to the machinery now on hand or still required for the work. So far, therefore, as the plant and its care and repair are concerned, the Government is better equipped to carry on the work as advantageously and economically as any contractor.

Many thousand employees have been secured, and an effective working organization has been perfected, and the recruiting system put in operation is capable of furnishing more labor than can be advantageously used. The employees are well sheltered and, in general, well fed; the salaries paid are satisfactory and the work is progressing smoothly. A change from these favorable conditions in the method of prosecuting the work would disorganize all existing conditions and would undoubtedly increase the estimated cost and time of completing the canal.

The conclusion that the work can be done better, cheaper, and more quickly by the Government has been reached only after free and full discussion by the various members of the Commission and the higher officials connected with the construction work, and after careful consideration of all sides of the proposition.




STEAM SHOVELS WORKING ON PARALLEL BENCHES ON EAST SIDE OF CULEBRA CUT, JUST SOUTH OF GOLD HILL.

SPREADING MATERIAL ON THE COROZAL DUMP.

LABOR, QUARTERS, AND SUBSISTENCE.

This department is charged with securing all skilled and unskilled labor and its assignment, according to the needs of the work. It is the custodian of all living quarters, allotting them to employees according to their standing as gaged by salary earned and in conformity with rules and regulations approved by the Commission.

It supplies furniture to quarters, delivers distilled water to residences, offices, and shops, and is in direct charge of the delivery of all food supplies, including ice, bread, and cold-storage articles from railroad stations or local commissaries to residences, hotels, messes and kitchens.

It polices the grounds around camps and quarters, cleaning up waste and refuse material which is placed within reach of those charged with its final disposition. It also has charge of the lighting of the camps and of roads to and through them.

It operates the hotels, messes, and kitchens for the accommodation of the employees of the different grades—the hotels for white Americans, the messes for Europeans, and the kitchens for the natives of the West Indies.

It keeps the service history of each individual employee in the general personnel record of which it is the

custody; issues by order of the chairman and enters thereon all orders pertaining to leaves of absence, sick leave, resignations, discharges, promotions, and reductions. It also authorizes the issuance of steamship transportation and special rates to which employees are entitled.

LABOR SUPPLY.—The skilled labor force is recruited in the United States. Agents of the Commission receive applications for all outside positions, personally examining the individual and looking into his previous service record. This includes trainmen, steam-shovel operators, foremen, and mechanics. Clerks, stenographers, draftsmen, doctors, and nurses are secured through the civil service registers. The skilled force on June 30, 1906, was approximately 2,500, and on June 30, 1907, actually 4,404. To increase this force 1,904 men and provide for the usual separations, due to sickness, resignations, etc., 3,038 men were brought from the United States during the year.

The unskilled force is brought from the West Indies and Europe. Recruiting agents are located in Barbados and Martinique, and a representative in Paris, France, to keep in touch with European labor conditions and with European emigration. On June 30, 1906, there were on the canal work 500 Europeans and 13,625 West Indians. June 30, 1907, there were 4,317 Europeans and 14,606 West Indians. To maintain this force of laborers, and also provide the Panama Railroad force of about 5,000 laborers, 6,899 Europeans and 10,947 West Indians were brought to the Isthmus—an average of nearly 1,500 men per month—to meet the demands of the work for common labor during the year.

The total force of skilled and unskilled laborers of the Isthmian Canal Commission and Panama Railroad on June 30, 1906, was 19,600, and on June 30, 1907, it was 29,446—an increase in the total of 10,000 men. During this period 20,884 men were brought to the Isthmus from the United States, Europe, and the West Indies. The labor problem is still an unsolved one, but the experiments of the past year with a diversity of races and nationalities has improved the efficiency of the force and promises to make the term of service longer. Tropical labor is migratory, and notwithstanding superior wages, housing, and subsistence, there will always be large periodical changes in the individual force. A regular recruiting organization, changed from one labor center to another, will always be necessary to keep a maximum force available.

QUARTERS.—At the close of the last fiscal year 1,129 houses were available for quartering employees of all classes, furnishing buildings for offices, hotels, messes, kitchens, and storerooms. On June 30, 1907, 2,208 buildings were in use for the same purposes. Considering the large increase in the skilled force and the number of women and children provided for during the past year, the number of people from the United States in quarters now, as compared with the close of the last fiscal year, is just about doubled, but they are all better and more comfortably housed than at this period last year. The congestion in the quarters of the common laborers has entirely disappeared, due to two causes, first, the completion of a great many houses during the past year, and, second, the fact that with improvement in efficiency it is not necessary to house as large a number of men as formerly.

SUBSISTENCE.—At the close of the fiscal year 15 hotels were operated for white Americans, where good wholesome meals are furnished for 30 cents each. These hotels are under the direction of stewards from the United States, and the cooks are generally Americans or men who have had experience in hotels and restaurants in the United States.

The Hotel Tivoli, at Ancon, is operated also for employees, but on account of superior accommodations and appointments higher rates prevail.

Eighteen mess halls are operated for the Europeans where a day's board is furnished for 40 cents. The stewards and cooks at these messes are usually Europeans, and a meal peculiar to the tastes of the men boarding there is served.

There are in operation 23 kitchens for the West Indian laborers, where a day's board is furnished for 30 cents and is made up of such food supplies as they are most accustomed to and prepared by cooks of their own country. The common laborer of the West Indies is employed upon a basis of subsistence being part of his compensation. This was found advisable on account of his careless habits and the fact that insufficient nourishment impaired his usefulness as a laborer, and sooner or later landed him in the hospital.

These hotels, messes, and kitchens are inspected daily by the supervising employees of the department of labor, quarters, and subsistence, and weekly by the district physician. All meats, vegetables, and food supplies are carefully inspected before they are used.

The number of meals served during the month of June, 1907, is as follows: Hotels, 197,419; messes, 286,155; kitchens, 456,765, or nearly a million meals for the month.

The subsistence operations are merely self-sustaining, and it is not the purpose to make a profit. They are operated upon the basis of contributing messes as far as possible.

SANITATION.

The work of sanitation was carried on throughout the year, increasing in amount and extent as new engineering construction was undertaken. Its success depends upon the ability to protect employees against the malarial mosquito, and this is accomplished by draining and clearing the ground in the neighborhood of villages, in addition to proper quartering. The following, in brief, is the work done in the Zone along these lines: Brush cut, 16,000,000 square yards; swamp lands filled and drained, 1,000,000 square yards; grass burned, 30,000,000 square yards; ditches dug, 217,000 linear feet; tile ditches laid, 50,000 feet, and cemented, 50,000 linear feet. Other functions were performed in addition, such as the disposal of night soil, the removal of garbage, and the care of cemeteries.

Too much credit cannot be given the department for the elimination of yellow fever, which permits the successful prosecution of the work. There was no yellow fever originating on the Isthmus during the year, though one case was brought in from shipping, the patient having passed the period of infection.

About 3,000 persons who had been exposed to yellow fever or smallpox were held in quarantine for observation.

The largest subdivision of the department has to do with the care of the sick, requiring for its maintenance more than half of the sums appropriated for sanitation. Medical attendance and medicines, both in the hospitals and in quarters, are furnished gratis to employees of the Commission and of the Panama Railroad. To the families of employees a charge is made for treatment.

The average daily force of skilled and unskilled laborers of the Commission and Panama Railroad was, at the beginning of the year, 19,600 and at its close 29,446. The average daily sick in quarters and in hospitals for the year was 916.

PANAMA RAILROAD.

The progress reported as being made during the previous fiscal year was continued during the past year. The rebuilding of the old line is completed and the building of the new double-track, with the exception of four miles from Gatun to Lion Hill, 90% of which is finished, is complete. Additional sidings and storage tracks, made necessary by the enormously increased business due to Commission dirt trains, were built. A block system of dispatching trains was put into use on the double track, affording the freest possible movement of trains consistent with safety.

The amount of traffic has been so heavy that the 70-lb. rails are proving too light and steps have been taken to increase them to 90 lbs., especially on the curves.

RECREATION FOR EMPLOYEES.

The four club houses, reported as under construction during the previous fiscal year at Culebra, Empire, Gorgona, and Cristobal, were completed and are now in operation, their management being placed under the Young Men's Christian Association. The club houses are under the control of an advisory board selected by the Commission. The influences of the club houses are excellent.

During the year a chapel was constructed at Ancon, and three buildings, one at each of the following places—Culebra, Gorgona, and Cristobal, appropriate for holding religious services and available for all denominations and creeds. The latter buildings are two-story structures, the upper floors of which are fitted as lodge rooms for various orders and societies formed among the employees. Another building of this type is in course of erection at Gatun.

MONEY STATEMENT.

APPROPRIATIONS.

| | |
|---|---|
| Total available appropriations to June 30, 1906 | $26,990,786.00 |
| Total appropriation year 1907 | 25,456,415.08 |
| Total appropriation year 1908 | 27,161,367.50 |
| Total appropriations | $79,608,568.58 |

EXPENDITURES.

| | | |
|---|---|---|
| Construction of canal | $29,782,682.60 | |
| Buildings | 5,862,384.90 | |
| Panama water-works, sewers and paving | 1,217,445.52 | |
| Colon water-works, sewers and paving | 763,302.30 | |
| Panama Railroad advances | 1,826,683.50 | |
| Total construction and engineering | | $39,452,498.82 |
| Government of the Canal Zone | $1,431,151.71 | |
| Buildings | 388,101.40 | |
| Zone highways | 499,023.70 | |
| Total civil government | | 2,318,276.81 |
| Sanitation and hospitals | $4,799,642.04 | |
| Buildings | 750,565.96 | |
| Total sanitation | | 5,550,208.00 |
| Loans to Panama Railroad | $1,631,257.34 | |
| Purchase of Panama Railroad stock | 157,118.24 | |
| Purchase Santa Rosa and Tivoli Hill properties | 56,882.96 | |
| Balance due by laborers for their transportation | 210,694.15 | |
| Bills rendered against Panama Railroad and others but uncollected | 463,988.52 | |
| Collections from individuals and companies remitted to United States Treasurer as miscellaneous receipts | 1,949,699.91 | |
| Labor furnished and material sold to Panama Railroad, Republic of Panama, Commission's employees, and other allied interests | 1,950,952.28 | |
| Cash and uncollected bills at various hospitals | 2,312.71 | |
| Total miscellaneous | $6,422,906.41 | |
| Less: | | |
| Amount due individuals and companies for claims allowed but not paid on this date | $505,375.18 | |
| Amounts unpaid on pay rolls.... June rolls: $1,290,419.14 Prior months: $141,327.07 | 1,431,746.21 | |
| Total amount of collections made and bills rendered and included in expenditures which have been or will be deposited in United States Treasury as— | | |
| Miscellaneous receipts | 2,873,146.63 | |
| Value of French material charged to the work or sold to individuals and companies which has been credited to purchase price of canal | 648,511.65 | |
| | 5,458,779.67 | |
| Net miscellaneous | | $964,126.74 |
| Total expenditures | | $48,285,110.37 |
| Balance available July 1, 1907 | | 31,323,458.21 |
| Total | | $79,608,568.58 |

The foregoing tabulated statement of appropriations and expenditures shows that $79,608,568.58 have been appropriated for the construction of the canal between the Atlantic and the Pacific oceans, and that of this amount, at the close of the fiscal year, a total of $48,285,110.37 was expended. The project adopted by Congress was estimated by the Board of Consulting Engineers to cost $139,705,200, exclusive of sanitation and expenses of the Zone government; the estimates submitted did not contemplate or provide for water-works, sewers, and paving in Panama and Colon, made necessary to secure improved health conditions, nor is any provision made for the re-equipment of the Panama Railroad.

GEO. W. GOETHALS,
Lieutenant-Colonel, Corps of Engineers, U. S. Army,
Chairman and Chief Engineer.

APPENDIX A.

REPORT OF MAJ. D. D. GAILLARD, CORPS OF ENGINEERS, U. S. ARMY, MEMBER OF ISTHMIAN CANAL COMMISSION, IN CHARGE OF THE DEPARTMENT OF EXCAVATION AND DREDGING.

Culebra, Canal Zone, August 21, 1907.

Sir: I have the honor to submit the following report of operations for this department for the fiscal year:

The total amount of material excavated in the Culebra division for the fiscal years ending June 30, 1904, 1905, 1906, and 1907 is given in Table I.

Previous to Jan. 1, 1907, much of the work done by steam shovels was of a preparatory nature and consequently the output was necessarily less than when the shovels had been established on a regular working basis. Moreover, the average number of steam shovels working during the first half of the fiscal year was only about 20, while for the last half of the fiscal year the average number was a little over 38.

It will be seen from Table II. that the maximum monthly amount of material excavated in the Culebra division during the fiscal year was 879,527 cu. yds., which was removed in April, 1907. This amount exceeds by 75% the maximum monthly excavation, as given in available records, made by the French in the Culebra division, their highest monthly total in the Culebra division being 502,250 cu. yds. in February, 1886.

With the exception of a very small proportion of material removed by hand from the quarry in the canal prism at Bas Obispo, all material is handled by steam shovels and dirt trains, and is carried to dumps situated at distances varying from 1 mile to 15 miles, the average haul at present being about 10 miles. This haul will increase in length, owing to the necessity of using material from the cut in the construction of the dams.

BLASTING.—The total amount of material actually mined during the fiscal year was 3,291,856 cu. yds.

The compressed-air plant was put in operation during the month of January, and all drills are now being run by compressed air. During the fiscal year 39 well, or mechanical churn, drills, were in operation, and 139 air drills.

The number of linear feet of holes drilled during the fiscal year were as follows:

| | Lin. ft. | Miles. |
|---|---|---|
| Steam and air drilling | 442,839 or | 83.9 |
| Well, or mechanical churn drilling | 167,052 | 31.6 |
| Hand drilling | 100,101 | 19.0 |
| Total | 709,992 | 134.5 |

The quantities of explosives used during the year amounted to:

| | Pounds. |
|---|---|
| Dynamite | 1,998,655 |
| Black powder | 408,385 |

STEAM SHOVELS.—At the beginning of the fiscal year 39 steam shovels had been received, but a large number of them had not been put to work. Up to the end of the fiscal year, 63 steam shovels had been delivered, erected, and accepted. These shovels are of three sizes, 45-ton, 70-ton, and 95-ton, with dipper capacity of 1¼, 2½, and 5 cu. yds., respectively.

The daily average number of shovels at work during the fiscal year ending June 30, 1906, was 9.17, and for the fiscal year ending June 30, 1907, 29.03.

The number of cubic yards excavated per hour, while under steam, by shovels not engaged in preparatory work, averaged 68 for the fiscal year ending June 30, 1906, and 86 for the year ending June 30, 1907.

The largest output during the fiscal year was made by steam shovel No. 218, a 95-ton shovel, which in 260 excavator days tooks out 211,055 cu. yds. of rock and 42,967 cu. yds. of earth, a total of 254,022 cu. yds. for the year.

Table III. shows the performance of steam shovels in the Culebra division for the fiscal year ending June 30, 1907. It must be remembered that this performance is based upon a working day of but eight hours, whereas contractors in the United States usually work their steam shovels about ten hours per day.

TRANSPORTATION.—The plant in operation under the transportation department on June 30, 1907, was as follows:

| | |
|---|---|
| Locomotives | 132 |
| Lidgerwood plows | 28 |
| Lidgerwood unloaders | 18 |
| Spreaders | 12 |
| Lidgerwood flat cars | 1,245 |
| 12-yd. Western dump cars | 267 |
| 20-yd. Western dump cars | 86 |
| 6-yd. old French dump cars | 198 |
| Ballast cars | 24 |

In addition the track and dump department had in operation three track throwing machines.

At the beginning of the fiscal year there were 65.8 miles of track in operation, of which 28.1 miles were laid with old Panama Railroad and Belgian rails. At the close of the fiscal year there were 106.78 miles of track in operation in the Culebra division, which is practically all of 70-lb. American steel.

LABOR.—The labor situation during the year has been very satisfactory, and at the present time no special difficulty is experienced in securing all the men needed in the various departments of the work. Better foremen are now being secured than in the past, and with more efficient foremen, the laborers themselves will necessarily prove more efficient.

On the Culebra division there are Spaniards, Italians, West Indian negroes, and a few negroes from the United States.

Spaniards and Italians are usually paid 40 cts. per hour silver, and West Indian negroes, when not furnished with meals, 20 cts. per hour silver. The prices just mentioned are for ordinary laborers. Firemen, drill runners, etc., receive higher wages.

The daily average number of laborers employed on the work during the fiscal year was 4,684. The daily average number in all departments during the previous fiscal year was 2,034.

During the year the wages of the gold employees of the Culebra division have been increased 8% on an average. This increase is almost wholly due to the continued prosperity in the United States, which necessitated an increase in wages in order to hold suitable men on the Isthmus.

COST.—Considering the total output in the Culebra division for the fiscal year, the average cost of the various items of expense have been as follows:

| | |
|---|---|
| Arbitrary, to cover cost of plant | $0.1200 |
| Blasting | .1451 |
| Excavation by steam shovels | .1081 |
| Transportation | .1942 |
| Tracks | .0830 |
| Dumps | .1548 |
| General expense | .0193 |
| Total | *$0.8245 |

In the table of costs just given the total cost of blasting has been distributed among the total number of cubic yards of excavation, but to get the real cost it should be applied only to the material actually mined, 3,291,856 cu. yds., making the cost for blasting $0.2557 per cu. yd. In other words, other things being equal, the removal of rock, due to blasting alone, costs $0.2557 more than that of earth.

*This does not include the material used in the repair of locomotives, steam shovels, and cars, nor does it include the cost of operating the air compressor nor the proportionate cost of administration and general expenses of the mechanical department, which makes repairs on plant for the Culebra division. These items have never heretofore been included in the cost of excavation in the Culebra division, but as they comprise a fair charge against this work, they will be included in the cost of work for the fiscal year ending June 30, 1908.

TABLE V.—CHARGES TO COVER COST OF PLANT.

| Item. | Charges per cu. yd. U. S. gold. | Remarks. |
|---|---|---|
| A. Steam shovels | $0.0075 | Includes cost of new shovels set up ready for service. |
| B. Cars | .0450 | Includes cost of new cars. |
| C. Engines | .0250 | Includes cost of new engines and rebuilding of French engines. |
| D. New appliances | .0100 | Includes cost of new appliances, such as unloading plows, spreaders, and unloaders. |
| E. Track material | .0175 | Includes cost of new track material. |
| F. Structures | .0025 | Includes cost of new structures, such as coal pockets, round-houses, powder magazines, yard offices, etc. |
| G. Miscellaneous equipment | .0025 | Includes cost of new steam and well drills, channelers, pile drivers, and other new appliances considered as working plant. |
| H. Contingencies | .0100 | Includes miscellaneous expenditures covering investment in plant. |
| Total | $0.1200 | |

The different items which go to make up this arbitrary charge of 12 cts. are given in Table V.

Up to Jan. 1, 1907, the arbitrary charge to cover cost of plant had been 6 cts. per cu. yd. of material excavated, but it was believed that this would be insufficient, and a value of 12 cts. per cu. yd. was adopted; but it is quite possible that this may have to be increased in the future.

The following changes were made in the organization of the Culebra division during the fiscal year:

July 11, M. K. Jones, appointed superintendent of transportation.
July 16, Jos. Little, appointed superintendent of excavation.
July 16, D. W. Bolich, appointed acting division engineer.
July 26, L. K. Rourke, appointed superintendent tracks and dumps.
August 31, H. F. Dose, resigned resident engineer.
October 22, A. S. Zinn, appointed resident engineer.
December 1, D. W. Bolich, appointed division engineer.

In comparing the cost of work upon the Isthmus with that of similar work in the United States, certain conditions existing in the former locality must be taken into consideration. The wages paid for skilled labor on the Isthmus are, on an average, from 40 to 70% higher than the same class of laborers receive in the United States. Their working day here is but eight hours in length, while on private enterprises in the United States the working day is usually ten hours.

In the greater portion of the eastern and southeastern part of the United States the price of soft coal does not exceed from $3 to $3.50 per ton. The coal used on the Culebra division during the fiscal year ending June 30, 1907, cost $6.48 per ton. Could this coal have been purchased for $3.25 per ton it would have reduced the cost of all excavation in the Culebra division for the fiscal year by 4½ cts. per cu. yd.

Owing to the long distance from the source of supply, machinery and material of all classes are more expensive than in the United States.

In addition to these disadvantages, the climate is not one conducive to great physical and mental activity, and the rainfall is so heavy—averaging about 95 ins. per annum for the Culebra division—that it interferes considerably with the rapid prosecution of work. This can readily be appreciated when it is remembered that the greater part of this rainfall occurs during the eight months comprising the rainy season.

TABLE I.—AMOUNT OF MATERIAL EXCAVATED IN THE CULEBRA DIVISION SINCE THE UNITED STATES ASSUMED CONTROL (PLACE MEASUREMENT).

| Fiscal year ending June 30— | From canal prism. Earth. | Rock. | Not classified. | Total. | Total excavation, including canal prism and accessory works. Earth. | Rock. | Not classified. | Total. |
|---|---|---|---|---|---|---|---|---|
| | Cu. yds. | Cu. yds. | Cu. yds. | Cu. yds. | Cu. yds. | Cu. yds. | Cu. yds. | Cu. yds. |
| 1904 | ..... | ..... | 60,107 | 60,107 | ..... | ..... | 60,107 | 60,107 |
| 1905 | 327,464 | 230,875 | 183,305 | 741,644 | 327,464 | 236,875 | 183,305 | 747,644 |
| 1906 | 764,327 | 742,235 | ..... | 1,506,562 | 764,327 | 742,235 | ..... | 1,506,562 |
| 1907 | 2,288,199 | 3,282,233 | ..... | 5,570,432 | 2,413,356 | 3,235,613 | 29,043 | 5,768,014 |
| Total | 3,379,989 | 4,255,343 | 243,472 | 7,878,745 | 3,505,089 | 4,295,723 | 272,515 | 8,076,327 |

TABLE II.—AMOUNT OF MATERIAL EXCAVATED MONTHLY IN THE CULEBRA DIVISION DURING THE FISCAL YEAR ENDING JUNE 30, 1907 (PLACE MEASUREMENT).

| Month. | From canal prism. Earth. | Rock. | Total. | Total excavation, including canal prism and accessory works. Earth. | Rock. | Not classified. | Total. |
|---|---|---|---|---|---|---|---|
| 1906. | Cu. yds. | Cu. yds. | Cu. yds. | Cu. yds. | Cu. yds. | Cu. yds. | Cu. yds. |
| July | 48,272 | 111,517 | 159,789 | 48,272 | 111,517 | ..... | 159,789 |
| August | 58,928 | 199,994 | 244,823 | 53,859 | 190,964 | ..... | 244,823 |
| September | 106,224 | 185,278 | 291,451 | 106,224 | 185,278 | ..... | 291,451 |
| October | 109,903 | 217,106 | 327,009 | 109,903 | 217,106 | ..... | 327,009 |
| November | 72,418 | 149,024 | 221,442 | 72,418 | 149,024 | ..... | 221,442 |
| December | 109,158 | 169,488 | 278,646 | 109,158 | 169,488 | 29,043 | 307,689 |
| 1907. | | | | | | | |
| January | 246,050 | 293,182 | 539,232 | 267,458 | 299,292 | ..... | 566,750 |
| February | 294,453 | 315,038 | 608,499 | 316,461 | 322,651 | ..... | 639,112 |
| March | 297,451 | 372,042 | 769,493 | 434,970 | 380,300 | ..... | 815,270 |
| April | 352,621 | 488,995 | 841,614 | 382,344 | 497,103 | ..... | 879,447 |
| May | 394,444 | 378,400 | 662,844 | 295,756 | 391,079 | ..... | 686,835 |
| June | 213,356 | 411,231 | 624,586 | 219,356 | 411,231 | ..... | 634,586 |
| Total | 2,288,190 | 3,282,333 | 5,570,432 | 2,413,356 | 3,235,613 | 29,043 | 5,768,014 |

TABLE III.—PERFORMANCE OF STEAM SHOVELS, CULEBRA DIVISION, FISCAL YEAR ENDING JUNE 30, 1907.

| Month. | Number of working days. | Output per shovel. Per day. | Per month. | Per hour under steam. | Per hour at work. | Rainfall at— Empire. | Culebra. |
|---|---|---|---|---|---|---|---|
| 1906. | | Cu. yds. | Cu. yds. | Cu. yds. | Cu. yds. | Inches. | Inches. |
| July | 25 | 238 | 5,441 | 91 | 144 | 14.61 | 20.26 |
| August | 27 | 336 | 14,461 | 73 | 144 | 11.94 | 12.97 |
| September | 24 | 360 | 13,664 | 70 | 142 | 7.41 | 6.22 |
| October | 27 | 523 | 14,573 | 69 | 147 | 3.97 | 5.46 |
| November | 24 | 450 | 10,833 | 66 | 122 | 21.05 | 19.19 |
| December | 26 | 491 | 12,367 | 66 | 132 | 8.15 | 9.09 |
| 1907. | | | | | | | |
| January | 26 | 702 | 18,248 | 95 | 170 | .08 | .08 |
| February | 23 | 674 | 15,946 | 66 | 102 | .13 | .49 |
| March | 26 | 741 | 18,530 | 100 | 171 | .16 | .68 |
| April | 26 | 765 | 19,894 | 104 | 201 | .09 | .04 |
| May | 26 | 853 | 21,674 | 111 | 190 | 6.22 | 7.45 |
| June | 25 | 663 | 16,568 | 90 | 151 | 13.65 | 14.74 |
| Fiscal year | 300 | ..... | ..... | ..... | ..... | 87.34 | 98.99 |

TABLE IV.—EXCAVATION BY DREDGES, COLON DREDGING DIVISION, SINCE THE UNITED STATES ASSUMED CONTROL (PLACE MEASUREMENT).

| Year ending June 30— | From canal prism, soft material. | From accessory works. Soft material. | Rock. | Total. | Grand total, from canal prism and accessory works. |
|---|---|---|---|---|---|
| | Cu. yds. | Cu. yds. | Cu. yds. | Cu. yds. | Cu. yds. |
| 1905 | ..... | 60,700 | ..... | 60,700 | 60,700 |
| 1906 | ..... | 904,945 | 92,500 | 997,445 | 997,445 |
| 1907 | 17,000 | 1,081,779 | 43,665 | 1,125,323 | 1,142,323 |
| Total | 17,000 | 1,996,424 | 137,165 | 2,083,468 | 2,200,468 |

COLON DREDGING DIVISION.

The Colon dredging division extends from the locks at Gatun to deep water of the Caribbean. The estimated amount of material to be removed from this division is nearly 21,000,000 cu. yds., of which about 3,700,000 cu. yds. consist of rock, and the rest of earth and mud. It is expected that all of this material will be removed by dredging, except about 700,000 cu. yds. in the vicinity of the Mindi hills, which will be removed by steam shovel.

DREDGING PLANT.—The dredging fleet now consists of one old French ladder dredge, one 5-yd. dipper dredge, and one 16-in. suction dredge. The dipper dredge is fitted with a 5-yd. dipper for soft material, and a 3½-yd. dipper for rock, and is capable of dredging to 42 ft. The hull is of steel, 110 ft. long, 38 ft. wide, and 10 ft. deep. This dredge cost $102,500. There is under contract with the Featherstone Foundry & Machine Co. a dipper dredge similar to that just described, which is to cost $100,000 delivered at Colon. This dredge should reach the latter place soon after the end of the fiscal year.

A contract has been made with the Maryland Steel Co., of Sparrows Point, Md., for two seagoing suction dredges —the "Ancon" and "Culebra"—similar to the "Manhattan" and "Atlantic," now operating in New York Harbor. Each of these boats has a length of about 288 ft., molded beam 47½ ft., molded depth of 25 ft., and is propelled by twin screws. They are each equipped with two 20-in. pumps, capable of digging to a depth of 40 ft. Their hoppers have a nominal capacity of about 2,000 cu. yds. The dredges are to be delivered at Sparrows Point, Md., at a cost for the two of $72,850, without equipment. Their hulls have both been launched, and the "Ancon" is expected to arrive at Colon early in August. The "Culebra" will probably not be finished before the latter part of September, and will then commence her long trip to Panama by way of Cape Horn, but will probably not arrive at Panama before January, 1908.

The total amount of material excavated by dredging, both in the canal prism and in accessory works in the Colon dredging division, is given in Table IV.

LA BOCA DREDGING DIVISION.

The La Boca dredging division extends from the locks at Pedro Miguel to deep water of the Pacific Ocean, but does not include the site of the locks at Sosa.

The estimated amount of material to be removed from this division, at the close of the fiscal year, is a little over 15,000,000 cu. yds., of which about 765,000 cu. yds. consist of rock and the rest of earth and mud. It is expected that all of this material will be removed by dredging, rock being blasted and then removed by a dipper dredge.

The old French ladder dredge (A2) spent 5,832 hours during the fiscal year in actual dredging; 501 hours un-

dredging repairs due to breakdowns; 966 hours in placing plant, changing crews, and other delays chargeable to dredging operations; 168 hours' delay were caused by passing ships, storms, and delays not chargeable to operation, and 1,293 hours were due to Sundays and holidays.

A total of 1,213,597 cu. yds. of soft material, place measurement, was removed by this dredge during the fiscal year, and the total cost of repairs, supplies, and wages of crews amounted to $125,463, making the cost per cubic yard of material removed for operation of dredge about 10⅓ cts.

The cost of dredging in this locality would be much cheaper were it not for the high price of coal—which costs $7.50 a ton delivered on board the dredges. The salaries paid the crews are also higher than are those paid for similar work in the United States. When these facts and the great tidal range are taken into account the figures given do not appear excessive.

## MEETING OF THE NATIONAL ADVISORY BOARD ON FUELS AND STRUCTURAL MATERIALS.

The annual meeting of the National Advisory Board was held at the Jamestown Exposition, Norfolk, Va., Oct. 25 and 26. This body includes an unusually large number of prominent technical men, as will be noted from the group picture accompanying this article. The organization of an advisory committee on testing of fuels and structural materials antedates the establishment of the Technologic Branch of the Geological Survey, as has been outlined before (Engineering News, Aug. 31, 1905, and Oct. 17, 1907). The members of this board serve without compensation and advise from their private experience or from the practice of concerns with whom they may be connected. Largely on this account, while the sessions are not exactly executive the proceedings are never published and the benefit to the public is reflected in the work of the Technologic branch, as that work may be benefited by the criticism and advice of the board. General statements concerning the sessions are allowed and on good authority we are able to present the following:

STRUCTURAL MATERIALS.—In the consideration of work upon structural materials the keynote of all the discussions was "the necessity of greatly increased testing facilities." The general method of procedure at these sessions consists of a presentation of the work done, the methods followed since the last session of the board, in each particular branch, and the general results about to be published. These papers are given by the persons in charge of the particular branches and are followed by questions and comments from members of the board.

Concerning the work on structural timbers presented this year, it appears that the properties of all kinds of tree timbers have been studied or determined, for very large sizes such as 12 × 12 ins. and over. Work has not been undertaken on small joist sizes. In the future, complete studies are planned on preservative-treated timbers, railway tie materials and built-up beams. It was recommended that new safety factors should be determined for various kinds of loading and study commenced on the behavior of woods under vibratory and intermittent loads, both distributed and concentrated in application.

In the discussions on reforestation it appeared that the scheme of providing by law certain tax rebates to farmers and land owners who planted trees systematically had proven useless in most places. In was also shown that in most lumbering localities of the country the taxes on land where lumbering is in progress, are such that the lumber operators must "skin the land" and afterward allow it to revert to the state in order that they may work at any profit.

The need for further testing was detailed as it appeared to the heads of the various government departments. In the Reclamation Service it was stated that every branch of human activity was concerned but great need was felt for more absolute knowledge of the action of cements and concrete. In the Treasury Department, which constructs government buildings, there was shown some apprehension as to the real actions of structural steel and concrete in large buildings. The designers of the works of the Panama Canal felt the same handicap and especially in the case of the enormous lock gates required, where, in some members, the stresses may be surprisingly great and the methods of calculation and design far from simple and exact. In all departments information was needed concerning the questions of impermeability, erosion, etc., of concrete structures.

The presence of occasional unexplained defects in ordnance and of "streaks" in ordnance steel was cited as an instance of ignorance that proper testing facilities might remove. This brought out a discussion of internal explosions in the ingot and consequent formation of pockets.

There was some discussion as to the need and the probable cost of a 10,000,000-lb. testing machine for tests of large structural members of metal. The administration of both the Watertown Arsenal testing laboratory and the Geological Survey testing laboratory, asked the Advisory Board to consider and assume the responsibility of determining the necessity of such a machine, recommending as to the branch under whose administration it should be placed and the location at which it should be operated.

Complete harmony was evident between these two branches, and indeed the fields of each were outlined for further investigations in the immediate future.

While it may be properly considered a digression, it is very interesting to consider, at this point, the recent statement issued by Mr. William R. Webster, M. Am. Soc. C. E., Consulting and Inspecting Engineer of Philadelphia, and Prof. Edward Marburg, M. Am. Soc. C. E., of the University of Pennsylvania, concerning the proposed investigation of steel and structural members to be conducted by the Watertown Arsenal. By the authority of the Ordnance Department, Messrs. Webster and Marburg were engaged to cooperate in the preparation of a program of tests. It is proposed, according to their statement, to conduct this investigation along lines of the greatest practical value to users and manufacturers. In these experimental studies of steel and steel products it is proposed to begin with the metal in ingot and to follow it out completely to the finished sections and built members. A meeting was held in New York City recently at which 25 consulting engineers and representatives of leading industrial interests were present for consultation with Major C. L. H. Ruggles, Commanding Officer of the Watertown Arsenal, and Mr. J. E. Howard, in charge of the Testing Laboratory, with a view to outlining the most desirable program for this investigation. The general opinion expressed at this meeting was that a study of the metallurgical questions of ingot structure, blooms, billets, slabs and forgings was highly desirable. A preliminary program was outlined for tests on structural mem-

McDonald
Fernald
White
Calvin
Smith
Robinson
Hunt
Humphrey
Howard
Holmes
Mahon
Nelson
D'Invilliers
Moldenke
Barrus
Woodwell
Dudley
Schneider
Gibbs

SOME OF THE MEMBERS OF THE ADVISORY BOARD AT THE JAMESTOWN EXPOSITION MEETING.

(Above are given the surnames of individuals in the group, arranged in the same relative position as the heads in the photograph. The full names are given in the article on p. 574.)

bers, such as columns, riveted tension members, riveted splices, riveted connections in building construction and on the general subject of riveting.

It was explained that the work was not to be regarded in any sense as a government investigation of steel, but that it was the desire of the Ordnance Department to utilize the increased appropriation of the Testing Laboratory with a view, not only of benefiting the government but also with a view of making the results as valuable as possible to all persons interested, whether as consulting engineers or as representatives of industrial interests.

The opinion was expressed that the testing facilities of the country have not kept pace with the advances and demands of engineering construction, and that the enlargement of the facilities at the Watertown Arsenal, by the erection of a machine of at least 10,000,000-lb. capacity, was desirable. It was decided to authorize Dr. C. B. Dudley, as chairman of one session to appoint two committees subject to the approval of the Watertown authorities; one committee on ingot structure, billets, blooms, slabs and forgings, and the other on tests of structural materials.

It should be remembered that this statement of Messrs. Webster and Marburg has no direct bearing on the work of the Advisory Board, and is quoted herein only because of its allied interest.

FUELS.—Unlike former sessions of the Advisory Board, the consideration of fuels was comparatively subordinated to that of structural materials, and was mainly on briquetted coal. Among the discussions was that concerning comparative tests made by one of the large railroads of the country, in conjunction with the members of the Geological Survey on a certain coal, in run of mine and briquetted forms. The advantages were marked in favor of the briquetted fuel over the natural which was very friable. Locomotive capacity was considerably increased and for medium loads the fuel cost per HP. substantially reduced. With the hand-firing of these tests, which might be above the average in quality, the production of smoke was very slight and dust in the fireman's cab was very largely eliminated. It was pointed out that these briquettes, made with water-gas tar-pitch as a binder and of a smooth surface, were non-porous and on the grate became miniature gas-producers whose internal pressure caused scale-cinders to be thrown off and away. The weathering qualities of bituminous coals were greatly increased by briquetting.

In regard to the use of briquetted coal in the navy, it was stated that if it could be demonstrated that they gave off no deleterious gases, were not bulky and held their shape they would be as desirable as coal, and that if there was greater ease in handling, less smoke in burning, larger steaming capacity of boilers and economy of fuel consumption, briquettes would be in demand on board the vessels. The cost of briquetting bituminous coals was stated to be in this country and abroad about $1 to $1.50 per ton, about 60 to 75 cts. of which represented binding material. In the course of the fuel discussions it was shown that the fuel testing officers were experimenting on better and cheaper binding substances.

On one afternoon of the sessions a test of briquetted fuel was made on the torpedo-boat "Biddle." Under one boiler was burned the briquettes and under the other, the natural coal. The boat was driven at a speed of 35 miles an hour. In the boiler used with the briquettes, better steaming conditions were realized than in the other, but with the production of more smoke. The latter condition was attributed to lack of experience on the part of the firemen in using briquetted fuel.

There were present at these sessions as members of the Advisory Board, guests or government test officers: Mr. G. H. Barrus, M. Am. Soc. M. E., Boston, Mass., Consulting Steam Engineer; Mr. John A. Brashear, M. Am. Soc. M. E., Astronomer, Allegheny, Pa.; Commander B. C. Bryan, Bureau of Steam Engineering, U. S. N.; Prof. Samuel Calvin, Iowa City, Iowa State Geologist; Capt. J. R. Cavanaugh, Engineer Corps U. S. A.; Mr. F. T. Chambers, M. Am. Soc. C. E., Civil Engineer, Bureau of Yards and Docks, U S. N.; Mr. C. B. Dudley, M. Am. Soc. C. E., M. Am. Soc. M. E., Altoona, Pa., Chief Chemist, Pennsylvania R. R.; Mr. E. V. d'Invilliers, M. Am. Inst. M. E., Philadelphia, Pa., Mining Engineer; Mr. T. L. Dougherty, Washington, D C., Mechanical Engineer, Treasury Department; Prof. R. E. Fernald, M. Am. Soc. M. E., Cleveland, O., Case School of Applied Science and Technical Branch, U. S. Geological Survey; Mr. A. W. Gibbs, Supt. Motive Power Pennsylvania R. R.; Mr. W. D. Gates, Chicago, Ill., Pres. American Terra Cotta and Ceramic Co.; Mr. A. A. Hammerschlag, Assoc. Am. Inst E. E., Pittsburg, Pa., Director Carnegie Technical School; Mr. C. A. Hexamer, Philadelphia, Pa., Past-President Nat. Fire Protection Assoc.; Col. Harry F. Hodges, M. Am. Soc. C. E., Washington, D. C., Engineer Corps U. S. A., Purchasing Officer Isthmian Canal Commission; Dr. J. A. Holmes, Washington, D. C., Chief of the Technologic Branch, U. S. Geological Survey; Mr. J. E. Howard, Watertown, N. Y., in charge of tests, Watertown Arsenal; Mr. R. L. Humphrey, M. Am. Soc. C. E., Philadelphia, Pa., Engineer on Cement and Concrete Tests, Technologic Branch, U. S. Geological Survey; Mr. Robt. W. Hunt, M. Am. Soc. C. E., Chicago, Ill.; Mr. Wm. Irvine, Milwaukee, Wis., President Nat. Lumber Manufacturers' Assoc.; Mr. R. S. Kellogg, Washington, D. C., Inspector U. S. Forestry Service; Mr. R. W. Mahon, West Albany, N. Y., representing Supt. of Motive Power N. Y. C. & H. R. R. R.; Mr. Hunter McDonald, Nashville, Tenn., Chief Engineer Nashville, Chattanooga & St. Louis Ry.; Dr. Richard Moldenke, Watchung, N. J., Secretary Am. Foundrymen's Association; Mr. E. D. Nelson, Pennsylvania R. R.; Mr. F. H. Newell, Washington, D. C., Director U. S. Reclamation Service; Admiral C. W. Rae, Chief of Bureau of Steam Engineering, U. S. N.; Mr. C. S. Robinson, M. Am. Soc. M. E., Youngstown, O., Vice-President Youngstown Sheet & Tube Co.; Mr. C. C. Schneider, Past President Am. Soc. C. E., Pittsburg, Pa.; Mr. G. O. Smith, Washington, D. C., Director U. S. Geological Survey; Mr. J. N. Taylor, Supervising Architect, Treasury Department, Washington, D. C.; Mr. I. C. White, Morgantown, West Virginia, State Geologist and Mining Engineer; Mr. H. M. Wilson, M. Am. Soc. C. E., Washington, D. C., Chief Engineer, Technologic Branch, U. S. Geological Survey; Mr. C. D. Walcott, Washington, D. C., Secretary, Smithsonian Institute; Mr. J. E. Woodwell, Washington, D. C., Inspcetor Electric Plants, Treasury Department; Gen. Wm. Crozier, M. Am. Soc. C. E., Washington, D. C., Chief of Ordnance, U. S. A. The larger number of these persons are shown in the accompanying figure.

## EMPIRICISM AND ERROR IN ARCH DESIGN.

By CHARLES W. COMSTOCK.*

The Board of Public Works of the City and County of Denver recently advertised for bids for the construction of a reinforced-concrete arch bridge, requiring each bidder to submit his own plans and specifications. The plans submitted differed so much among themselves that it was evident that the designers had radically different ideas regarding the analysis of such structures. A careful examination of the various plans together with the correspondence which grew out of the competition conduced to the opinion that there is an astonishing confusion of ideas in the matter of arch design and that there is room for further discussion of the subject in the technical press, notwithstanding the large amount of space heretofore devoted to the matter.

Tables of stresses resulting from stated loadings, though called for, are seldom forthcoming in such competitions as the one above referred to. Instead we get lengthy statements of the alleged impossibility of calculating these stresses. Many of the bidders seem to arrive at the principal dimensions of their designs either by empirical formulas or by comparison with the dimensions of some apparently similar structure which has not yet fallen down and which is, therefore, declared "satisfactory."

A mere rule for fixing dimensions is not to be compared with a method of analysis, of course. Structures proportioned by empirical rules of the nature of those prevalent in arch design are certainly open to question in that their margin of safety is entirely unknown. The writer's own view is that none of the so-called "methods" of arch analysis are worthy the name except those which are firmly founded on the general theory of elasticity.

Perhaps the error most commonly made is to confound the calculation of stresses with the determination of load distribution on the arch. One correspondent writes:

> To apply the elastic method to an earth-covered arch requires first that the earth filling over the arch shall be assumed to rest vertically upon the extrados of the arch.

This is clearly absurd. The earth pressure may be assumed to have any direction, intensity and distribution whatever, without affecting the manner of calculation. Any uncertainty as to the actual forces to be resisted by a structure is common to all methods of calculation. To contend that the theory of elasticity is not properly applicable to an arch is as though one should say that the ordinary beam formula is useless when applied to a lintel spanning an opening in a solid wall. The same uncertainty exists in both cases, but the method of determining stresses is not responsible for the uncertainty in either case. In short, there are here confused two problems which must be carefully separated: First, determine as exactly as possible the forces to be resisted; second, determine the consequent stresses in the most accurate manner.

In the same letter appears this statement:

> Another assumption that is always made by those who treat the elastic method is that the elastic arch is supported upon inelastic abutments, and thus are derived the three fundamental equations of summation which determine the force polygon. This assumption is a serious error, and every such analysis results in showing tension at the inner face of the arch at the springing, even for very flat spans, which is quite contrary to fact.

It is indisputable that the stresses in an arch are influenced by yielding of the abutments and it is, therefore, obvious that any method which pretends to determine these stresses without regard to the condition of the abutments is fallacious. It is usual to assume that the abutments are unyielding because they can and should be made so massive and rigid that their motions and deformations will be infinitesimal as compared with the deformation of the arch itself. However, this assumption is not necessary and the designer can readily determine the effect on the arch stresses of any assumed motion of the abutments. The difficulty of determining how much the abutments will actually move is an entirely different matter and applies alike to all methods of calculation. Having constructed the best abutments which the conditions will permit, the designer can form an opinion as to the greatest motion which will take place and then determine the maximum stresses resulting from any condition between this assumed motion and absolute rigidity. The arch should then be proportioned for these maximum stresses. The obligation to do this certainly rests on the designer of any important structure.

It is difficult to understand on what the statement that "every such analysis results in showing tension at the inner face of the arch at the springing" is based. The writer has analyzed a considerable number of arches and has found that nearly always (and in the case of very flat spans always) the reverse is true: the tension is shown by the analysis to occur at the extrados at the springing. With a greater rise the analysis may show tension at the intrados, and that this may actually occur is shown by one of the tests made by the Austrian Society of Engineers and Architects. This was a concrete arch of 23.00 m. span and 4.60 m. rise reinforced with one network of steel rods near the extrados and another near the intrados; the ring was 350 mm. thick at the crown and 600 mm. at the spring-

*Civil and Mining Engineer, Boston Bldg., Denver, Colo.

ing. The structure was tested to destruction by a load symmetrically distributed over one-half of the span. The line of pressure was drawn as the result of a careful analysis by the theory of elasticity and showed that tension was to be expected on the unloaded half at the intrados at the springing and at the extrados at the haunch, and on the loaded half at the extrados at the springing and at the intrados at the haunch. When tested to destruction, not only did tension cracks develop at these points but they were confined to the zones indicated by the analysis and did not develop elsewhere. In addition to the reinforced arch, tests were conducted on an arch of rubble stone masonry, one of brick and one of concrete not reinforced, all of the same span and rise as the reinforced arch. The cracks developed in these arches by the tests all conformed to the predictions of the analysis. These facts indicate to me that the method of the analysis used in this case is correct and reliable.

In Castigliano's "Théorie de l'Equilibre des Systèmes Elastiques" may be found an analysis of a metal arch with open spandrels, the span being 45.00 m. and the rise 5.50 m., which shows very clearly a region of tension at the extrados at the springing. In the same book there is an analysis of an arch-ring constructed of cut granite with a backing of rubble masonry and earth and having the same span and rise as the metal arch just mentioned. This shows that the pressure reduces to zero at the extrados at the springing, the arch having been proportioned to avoid tension at any point. Castigliano also analyzes a brick arch of 42.00 m. span and 11.90 m. rise backed with rubble masonry and earth, and finds that the center of pressure at the springing line nearly coincides with the center of the ring, though there is a slight tendency to tension at the intrados.

These facts do not bear out the statement that "every such analysis" shows tension at the intrados at the springing, nor does it appear that in those cases where such tension is indicated, it is necessarily "quite contrary to fact."

In another letter appears the following:

> In the elastic method we first assume the tangents to the curve at the abutments to be fixed. This enables us to arrive at the three fundamental equations. Solving an arch by these three equations we find that the maximum moment occurs at the point where we have previously assumed the tangent to be fixed. If, then, the concrete is elastic, the tangents will shift and upset all of our assumption.

Here is an erroneous association of ideas. The change of direction of the tangent is not the result of the moment at the point of tangency. In the case of an arch with hinged ends the change of direction of the tangent is greatest at the hinge, though the moment at that point is zero. A little attention to the ordinary theory of beams will furnish many illustrations of the same principle. In a beam supported at the ends and uniformly loaded the moment is greatest at the center where the tangent does not change direction at all, while it is zero at the ends where the change of direction is greatest. In a beam fixed at the ends the moments are greatest at the ends and in the middle where there is no change of direction of the tangents, while at the points of inflection where the moments are zero the change of direction of the tangents is a maximum. In short, the idea contained in the above quotation leads at once to a reductio ad absurdum in that fixation of the tangents produces bending moments which in their turn cause the tangents to move. The fundamental facts which have been entirely overlooked by our correspondent are that the effect of a bending moment at a particular point of a prismatic body is to change the curvature at that point regardless of whether the tangent changes direction, and that the change of direction of the tangent is the cumulative effect of all the bending moments on one side of the point in question which effect may be positive, negative or zero.

It is further asserted that in the application of the theory of elasticity it is arbitrarily assumed "that the arch should be a circle or a parabola or other simple curve for the sole purpose of simplifying the analysis by the elastic method." This is an entirely mistaken idea. In nearly all cases the form of the arch is fixed by esthetic considerations based on the surroundings and the profile of the crossing, or with regard to the ease of construction of the falsework. So far as the method of calculation is concerned it makes not the slightest difference what the form of the arch curve may be.

It is so frequently stated that the application of the theory of elasticity is based on this or that assumption, that it may be well here to state the only assumption underlying the modern theory. It is nothing more than the proportionality of deformation to the force producing it and is the basis of every formula we have for calculating the resistance of materials in any form. It is not properly called an assumption at all since there is an abundance of experimental evidence in its favor. The formulas derived from it are furthermore not confined in their application to perfectly elastic bodies, but are also useful for imperfectly elastic materials. This point is very concisely stated in the following paragraph from Castigliano, which I quote as printed, that I may not be accused of distorting the author's meaning:

> Si, de plus, la compressibilité des corps imparfaitement élastiques composant les systèmes considérés est proportionnelle aux pressions, ainsi que cela a lieu, entre certaines limites, pour les corps parfaitement élastiques, il est facile de voir que la distribution des forces intérieures se fait exactement de la même manière que dans ces derniers corps. D'où il suit, que les formules et les théorèmes que nous avons démontrés pour les corps et les systèmes parfaitement élastiques, auront lieu aussi pour les corps et les systèmes imparfaitement élastiques; dont le cas qui se présente le plus souvent dans la pratique, est celui des arcs en maçonnerie, lorsque les mortiers n'ont pas encore fait bonne prise.

In response to a reference to the arch tests conducted by the Austrian Society of Engineers and Architects one man writes: "There were no reinforced arches tested by the Austrian Society." Since this statement may have received general circulation and may be believed by many persons, I take this occasion to refer to the report of the Gewölbe-Ausschuss of the Austrian Society of Engineers and Architects in which will be found records of tests as follows: two Monier arches of 2.70 m. span, one Melan arch of 4.00 m. span, one Monier arch of 4.05 m. span, one Monier arch of 10.00 m. span and one Monier arch of 23.00 m. span. This is certainly a record worthy of attention and entitled to some weight.

At various places I find references to the supposed necessity for confining the line of pressure to the middle third of the thickness of the arch ring. Some people seem to have forgotten the significance of the "principle of the middle third." It is nothing more than a convenient way of expressing the fact that there is to be no tension at any part of the ring. This, of course, is necessary with block masonry, whose resistance to tensile stresses is extremely small and may be even zero at the joints. However, with reinforced concrete, designed to resist the tensions which may occur, this necessity no longer exists. In such a structure it becomes necessary to determine the actual stresses in the concrete and in the steel that they may be known not to exceed certain limits previously fixed upon as safe working stresses for the materials in question. If this condition is fulfilled it is of no importance where the line of pressure may lie with respect to the arch ring. Of course, if the line of pressure lies near the axis of the ring less reinforcement will be required, but this is an economic rather than a technical matter. The principles involved and the method of calculation will be the same in any case.

In another letter appears the following:

> Having a given loading, there is but one curve that will prove most efficient, and that is the curve that is freest from bending moments. No one has been able by theoretic methods to determine what that curve should be for an arch covered with earth filling. . . . Our experience has shown us that the curve as determined by our method of design is practically the linear arch for the earth loading, and is consequently free from bending moments except those due to live load.

As pointed out earlier in this article the difficulty in determining the curve of the linear arch for earth loading is entirely due to the uncertainty as to the direction and magnitude of the earth pressure. Given these data the determination of the linear arch is a simple matter. The fact is that the problem of the pressures on any plane within the mass of a pulverulent material, such as earth, is not one permitting of a unique solution as do those of hydrostatics and of the theory of elasticity. A mass of pulverulent material may be in equilibrium under a wide range of stresses on a given plane, and it is therefore impossible to do more than determine the limits within which these stresses must lie. For any assumed distribution of pressures within these limits it is possible to find the curve of the linear arch, and the arch ring constructed to carry an earth loading must be capable of resisting the pressures due to any one of these linear arches. Since the pressures within the earth mass may and undoubtedly do change from time to time due to the influence of varying degrees of moisture and to rearrangement under the action of the live load, it seems clear that an arch of such form as to be free from bending moments under the earth load as originally applied may be subject to very considerable bending moments after the earth pressures have been rearranged by use of the bridge. Under these circumstances it is hardly worth while to waste very much time or thought on the form of the arch curve except as it may affect the appearance of the structure, and it is certainly not safe to shave the arch ring down to a minimum on the assumption that it is free from dead load bending moments. "Our method of design" mentioned above appears to consist of a simple geometrical method for constructing the curve of the intrados, together with an empirical rule for the thickness of the arch ring at the crown; and the experience which has shown "that the curve * * * is practically the linear arch for the earth loading" seems to have consisted in the construction of a large number of such bridges which have not fallen down. Upon this basis almost any designer would be warranted in concluding that nearly any curve is the linear arch for any loading.

In another place this same correspondent writes:

> In the last five years we have designed and erected upward of five hundred bridges of the type submitted for ——. For three years we depended largely upon elastic methods of design, but for the last two years have been able to secure more satisfactory results by the use of our empirical formulas, which are based upon three years' experience with the elastic method.

An empirical formula is properly found only by assuming the form and then determining the constants so as to secure the best possible agreement with a large number of observed facts. Unless this is done with great care calculations made by the resulting formula will partake very much of the method of the astronomer who declared that the way to find the distance to a star is to "guess at a quarter of it and multiply by four." Even though the constants be determined with the greatest care there is no warrant for the use of such a formula outside of the limits of the observations by which the constants have been determined. Our correspondent has apparently determined the constants of his formulas by comparison with his designs based on the theory of elasticity, and now regards these formulas as more reliable than the theory on which they are really founded. Blind faith in a formula rather than proper consideration of the physical facts which it is intended to represent frequently leads to this untenable position. It would be interesting to know how this gentleman determines that his results are "more satisfactory" by his present method than by the former and in what units he measures his satisfaction.

In the above quotations and comments the writer has carefully avoided mentioning names, since it was not intended to attack either the individuals in question or the designs submitted in the Denver competition, but simply to controvert erroneous and unscientific claims or statements relative to the design of reinforced concrete arches.

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**A DRAWBRIDGE ACCIDENT** occurred at Chicago, Nov. 19, when the freight steamer "Joseph Langdon" struck the north end of the Clark St. bridge. The steamer was coming up the river early in the morning, but when it whistled for the bridge to be opened a street car was on the bridge. The steamer was not prepared for the delay, and could not be stopped before it struck the bridge, carrying away part of the railing and sidewalk and damaging the abutment.

## THE PHOENIXVILLE TESTIMONY IN THE QUEBEC BRIDGE INQUIRY.

The Canadian Government Commission charged with inquiring into the collapse of the Quebec Bridge and all that pertains thereto has completed the taking of testimony in the United States, and therewith has practically completed its labors preliminary to drawing up its report. The testimony taken here included that of the Consulting Engineer, Mr. Theodore Cooper, and that of the engineers and officials of the Phoenix Bridge Company, who was constructing the bridge. Mr. Cooper's testimony we presented in full in our issue of Oct. 31, 1907, pp. 473-477. We are now able to give with substantially the same completeness, the testimony taken at Phoenixville. In conjunction with the testimony of Mr. Cooper, it presents a remarkably complete picture of the Quebec Bridge work.

The verbal testimony, as here given, is, of course, only a part—a small part—of the evidence gathered by the Commission at Phoenixville. An enormous volume of correspondence, many record books, and large files of plans and calculations were obtained and examined, the works and equipment for manufacture were thoroughly studied and all phases of the bridge construction were investigated. The formal interrogation here recorded was conducted subsequent to the principal mass of the work, after all the available facts had been ascertained, and was so arranged as to bring into concise form the information pertinent to the inquiry possessed by the Phoenix Bridge Company, or its individual officials.

### Testimony of DAVID REEVES, President of the Phoenix Bridge Co., and President of the Phoenix Iron Co.

[In Extract.]

Mr. Reeves has for many years been at the head of both the Phoenix Bridge Company and the Phoenix Iron Company. In 1872 he became a partner in the firm of Clarke, Reeves & Co., the other partners being the late Thomas C. Clarke and Mr. A. Bonzano. In 1884 this firm was incorporated as the Phoenix Bridge Company and the Phoenix Iron Company, the business being separated into the manufacture of steel and bridge work and the design and erection of bridges. Mr. Reeves' statement before the Quebec Bridge Commission defines the relations of the two companies to each other and to the Quebec Bridge work, and expresses the general views of the Phoenix Bridge Company relative to the disaster. We have omitted portions of Mr. Reeves' testimony on account of the space necessary for the testimony of other officers on matters of especial interest to engineers.

Q. Is the Phoenix Bridge Co. a manufacturing company at all, or is it entirely a contracting company, and is it entirely separate from the Phoenix Iron Co.? State the relations between the companies.

A. The Phoenix Bridge Co. is an engineering and contracting, not a manufacturing company. It is entirely separate from the Phoenix Iron Co. It has an arrangement with the latter under which its bridge and other structural work is manufactured in accordance with requirements. Formal methods of accounts, charges and payments are administered between the two companies precisely as in other contracts.

. . . . . .

Q. Does the Phoenix Bridge Co. provide material for and carry out the manufacture of all work under the contracts made by the Phoenix Bridge Co.?

A. The Phoenix Iron Co. provides the materials and fabricates the shop work in its mills and shops in accordance with the specifications and plans furnished by the Phoenix Bridge Co., under its directions.

Q. Is this under a regular standing arrangement, or is there a separate arrangement made for each piece of work?

A. This is done under an arrangement standing since 1884 and prior thereto with the predecessors of the Phoenix Bridge Co., the firm of Clarke, Reeves & Co.

. . . . . .

Q. Did you keep in touch with the Quebec Bridge work as it proceeded, with what matters did you more especially concern yourself, and, in view of what has occurred, will you please state fully all the circumstances of your own knowledge and your comments upon them?

A. I kept in touch with the work at all stages of its progress. I fully appreciated its magnitude and importance, the engineering difficulties involved, and the necessity of the highest class of workmanship in all members of the bridge. I believed the appointment by the Quebec Bridge Co. of Theodore Cooper as Consulting Engineer assured the success of the undertaking, that our engineers and constructors were fully competent to design, construct and erect the bridge under Mr. Cooper's supervision and that of the engineers of the Quebec Bridge Co. and of the Department of Railways and Canals.

Mr. Cooper insisted upon reserving to himself the final authority over his colleagues, and I especially regarded his approval of the detailed drawings as of the highest importance, believing that with the details and sections of the bridge members approved by him, as well as the general procedure in shop and field, a perfect organization existed. I never suspected he was overworked, and I believed he would have been allowed any assistance asked for. I was advised that the Department of Railways and Canals intended to appoint an assistant engineer with a staff to actively cooperate with him, but was prevented at Mr. Cooper's imperative demand. . . . .

Mr. Cooper was in the shops but twice, only once saw any of the finished bridge members and was never at the bridge site at all after erection started, and consequently did not see or know of much of this preliminary work, and was not familiar with the processes by which the bridge members were constructed. But his inspectors and our inspectors, working independently as checks upon each other, did not use their usual discretion, but I understand reported every error, however slight, directly to Mr. Cooper for his information and approval.

This was an extra precaution on account of the importance of the work. It probably caused Mr. Cooper, who never saw the matters in question, to magnify their importance and to believe an unusual number of errors had been made, which is not true. On the contrary, very few errors were made, and all were properly and fully corrected before shipment in the most workmanlike manner. No member left the shops that was not fully inspected and accepted by the representatives of the Quebec Bridge Co.

The erection of this bridge was an important undertaking, and every precaution was taken to avoid unnecessary risks, and our whole organization was impressed with this idea. Every one who observed its progress regarded it as a remarkable instance of performance in accordance with a prearranged plan, as a masterpiece of erection. When the compression chord members began to yield at several places one after another, as we can now see, and the whole bridge was on the verge of collapse, as afterwards dveloped, our staff at the bridge site observed the signs, and acted promptly and efficiently. They calculated correctly the stresses on the several members, and decided that failure from such stresses was impossible. When reported to Mr. Cooper he foresaw no immediate danger, and the same was true at the office of the engineers at Phoenixville. After the event we have learned what we did not know and could not have known before.

Mr. Cooper states he could have saved the bridge, that he now knows the weakness of the members that failed and could have remedied them at the cost of $100, but he does not say how, nor did he tell Mr. McLure on Aug. 29 when he called on him, nor did he tell any one else, when the information might have been acted upon. I believe from all the evidence that was available at the time, there was no possible way to save the bridge, and the impending catastrophe could not have been foreseen or averted.

I believe that no engineer is able to state positively the cause of the failure or would wish to undertake to strengthen the compression members now built for the north side until after a satisfactory number of built-up compression members of corresponding design of the largest possible section had been tested to destruction; but I think it is now possible to foresee that after such tests have been made the members already built for the north side can be increased in section, and made perfectly safe for use at a comparatively small cost, and that new members can be made for the south side to correspond exactly.

We shall be glad to put our testing machine at the disposal of the commisison and to make when desired a series of tests upon it for this purpose, up to a cross-section of about 80 sq. ins.

In respect to the sections of the compression members as built up for the Quebec bridge, I wish to say that it was not to the interest of the Phoenix Bridge Co. to restrict the area or weight of these, as has been intimated, but that in a commercial way it was largely to its interest to increase the sections, and the size and weight of the bracing, and from that point of view we should have been glad to have increased the weight. Our contract being not for a lump sum but by the pound, any increase of metal would have been to our advantage.

It was simply imperative from the point of view of good engineering, and in accordance with the fundamental requirements of the contract and specifications, not to make the weight or the price of the bridge any more than was demanded by the best practice. The Consulting Engineer in the interest of his clients was supreme in this respect.

We proceeded with the contract, unrestricted [illegible] any consideration of the financial strength of the [illegible]pany which employed us. No restriction of that kind [illegible] ever heard of by us—we were always promptly paid, [illegible]d we never economized in any respect by reason of [illegible] such consideration. It can be seen now that some in[illegible]se of weight was requisite, especially in certain com[illegible]sion members, and prior to the shipment of any [illegible] these members we called this matter to the attention [illegible] Mr. Cooper, but Mr. Cooper would not allow any [illegible]rease whatever in these members, and decided they fu[illegible] met the requirements.

There was no undue haste. Progress in the d[illegible]ing-room was always retarded while the engineers [illegible]cked and rechecked their calculations. Progress in the [illegible]hops was always retarded while the drawings were be[illegible] examined and approved, and rechecked to provi[illegible] for every possible condition of loading during erecti[illegible] and after; and progress in the field was always subject [illegible] delays by the engineers on the bridge who controlled the operations of the erectors, and saw to the proper level and alinement. Due expedition was essential from many points of view, but it was never permitted at the expense of safety or good workmanship. . . . . .

The cause of the failure cannot be found due to any departure from the specifications in design, material or workmanship, or lack of good judgment in the field. No engineer under the circumstances will accept the idea of a local defect to account for it. The profession is bound to look beyond that—in the employment of the unusually high stresses prescribed for compression members, beyond all precedent and, as it now appears, beyond the existing technical knowledge of their effect.

. . . . . .

Mr. Cooper made modifications in the unit-stresses to be employed upon the various members which very much increased them beyond any precedent, and by so doing placed the whole design in a field outside the benefit of experience. Such high stresses had never before been used, and in using them he acted with the authority of the Quebec Bridge Co. and the Dominion of Canada vested in him. The fall of the bridge is to be laid directly to the change in the unit-stresses as made by Mr. Cooper.

### Testimony of FRANK P. NORRIS, Manager of the Phoenix Iron Co.

[Very slightly condensed.]

As manager of the Phoenix Iron Co., directing the operation of the steel furnaces, rolling mills and bridge shop of the company, Mr. Norris was in charge of the fabrication of the Quebec Bridge material and of the rolling of most of its material. He devoted himself very energetically to this particular part of the work under his charge, as his testimony shows. He has been in this present position since February, 1900, prior to which period, from May 1, 1896, he was Assistant Superintendent of the works. He is in charge of the works under Mr. Wm. H. Reeves, General Superintendent, and the President, Mr. David Reeves. He has no connection with the Phoenix Bridge Co.

Q. What was the date you were first officially advised to prepare for the construction of the Quebec Bridge and who so advised you?

A. In the spring of 1900 I was advised by Mr. Wm. H. Reeves, General Superintendent, that we were likely to receive instructions very soon to proceed with the Quebec bridge and that it was important that we look carefully into the question of the manufacture of the eyebars for top chords and diagonal tension members, and at the same time stated that no bars must be used in the structure over 2 ins. in thickness, as he was satisfied from past experience that bars over 2 ins. in thickness were not as efficient as those of this thickness or less.

Q. Prior to June 19, 1903, what work had you done in the shops in anticipation of having to build the Quebec bridge, and under whose authority was this done?

A. The work done in shops prior to June, 1903, in anticipation of having the Quebec bridge to build was as follows, and was authorized by Mr. William H. Reeves.

It was thought by some that we could not forge bars of such large dimensions, namely: 15 ins. × 2 ins., with eyes of proper width to suit the different sizes of pins that would be necessary to use. We had frequent discussions as to how we would make these large eyebars for the Quebec bridge. It was thought by some that we would have to cut them out of plates. Owing to the immense size of the bars it would have been next to impossible to get plates large enough, some of the bars requiring eyes 35½ ins. in diameter and the bar measuring 85 ft. in length, which would have required a plate 36 × 2 ins. × 85 ft. 6 ins., weighing 20,948 lbs., which no mill in the world could roll. I then made up an estimate showing the comparative cost of upsetting and forging these eyebars from a 15 × 2-in. bar and of cutting them from a solid plate. This estimate was made

up Aug. 28, 1900, and satisfied us that cutting bars out of plates was out of the question and that forged bars must be used.

After much thought I formed the opinion that by making certain changes to our eyebar upsetting machine we could upset and forge these 15-in. bars and obtain much better results than by cutting them out of large plates. To show that this theory was correct we made the changes necessary to the upsetter, made dies for hammer and all necessary appliances for forging 15-in. bars, and on Oct. 6, 8 and 9, 1900, we forged ten 15 × 2-in. bars and tested two bars, one on Oct. 12 and the other on Oct. 13, test report herewith attached. This experiment cost in the neighborhood of $1,000, and proved that we could make the bars and thus avoid delay in design of the bridge.

We were expecting to receive instructions any day to proceed with the bridge and we were thoroughly aware of the fact that before the fabrication of the different members was begun in the shop, owing to the immense size and weight, we should have to erect numerous large traveling cranes and secure a large number of new machines to do the shearing, straightening, milling, boring, etc., as tools for ordinary work were nowhere near large enough to take care of work of the magnitude of the Quebec bridge. Owing to the size and length of these sections it was necessary to make certain additions to our main bridge shop and strengthen the columns that supported the crane runway girders, and also replace the old runway girders with much stronger ones in order to carry the heavy loads. We did this work in the fall of 1902 as we realized it would take considerable time, and decided to make these improvements at once rather than to take chances of delaying the work.

The above changes to crane runways and additions to shop cost us between $28,000 and $30,000.

Q. After the date of the contract between the Phoenix Bridge Co. and the Quebec Bridge Co., June 19, 1903, what special preparations were made in the shops for the manufacture of the bridge?

A. On June 19, 1903, the formal contract for the Quebec bridge was signed and I was instructed to proceed at once to obtain whatever machinery and tools were needed to make the best job possible, regardless of their cost, and these instructions were carried out to the letter. Our total cost for extensions to plant, machinery, tools, cranes etc., necessary to build the Quebec bridge, was between $225,000 and $250,000.

Q. At what date was the manufacture of the steel commenced? At what date was the first working drawing given you, when was the shop work commenced and upon what member?

A. Manufacture of steel was commenced June 14, 1904, for the tower shells. The first working drawing was received at shops on June 1, 1904, and was for strut T. S. 3, between tower shells (the orders for the metal having been sent to the mills several days previous to sending drawings to shops). Shops started to punch the metal for this strut June 24, 1904.

Q. At what date was material ordered for lower chords and at what date was work on them begun in the shop?

A. Material was ordered for No. 1 Chords, 606 South Anchor Arm, on July 19, 1904, and shops started to punch the metal for them Aug. 5, 1904.

Q. Will you please state from your personal knowledge the main facts in the course of manufacture as they concern you and any comments you have to make upon them?

A. Every department superintendent, as well as the workmen in the steel plant, rolling mills, bridge shop—and in fact all employees of the works, were instructed to take the utmost care in preparing and handling the material for this bridge, as well as the punching, assembling, reaming, drilling, milling, boring, planing, etc. The engineers furnished the shops with drawings showing just how all the large members were to be loaded on the cars for transportation to Quebec, and numerous special appliances were employed for this purpose. All these instructions were followed with the greatest care.

During the months of May and June, 1904, we made a full-size model of a panel point of the anchor arm to let our shop men see the size of the members we had to build, and to further impress upon them the magnitude of the work and the great importance of building the work just right, and also that they could familiarize themselves with details and avoid the possible chances of mistakes in the shops. This model cost between $600 and $800 to build, and can be seen on the second floor of the bridge company's office.

All the shapes for this bridge were rolled in our works; the plates were furnished by the Central Iron & Steel Co. and the pin material by the Bethlehem Steel Co., and inspected at the different mills by the inspectors appointed by the Consulting Engineer.

After the chords, posts, etc., were riveted up complete, they were laid out by the shop superintendent personally—in his absence by his assistant—before being placed in the rotary planers (for facing) and boring mills and were checked up after each cut to make doubly sure the work was being done correctly. In many cases, if not always, these layouts were checked by either Mr. Edwards,* or Mr. Meeser,* as an extra precaution, and were always checked by the Phoenix Bridge Co.'s inspector. We threw every safeguard possible around this work to avoid error, and, notwithstanding, a few minor errors did creep in, but none of a serious character. They were remedied to the entire satisfaction of the Consulting Engineer's representative. The Chief Inspector of the Phoenix Bridge Co. kept a complete record of all variations from the drawings, even to the chipping of a rivet.

When the question of inspection of the Quebec bridge in the shops was first brought up I made a strong plea that the best shop inspectors that were obtainable should be placed on the work. The Consulting Engineer, as I remember, stated distinctly that he would not have the inspection done by an inspecting firm as he wanted men of his own selection who should have no duties but to be right on this work all the time. This met with my ideas exactly, except that the Consulting Engineer stated that he wanted young men just out of college who, being without any practical experience, would be trained according to his own ideas. This, I, as well as other officials of the company, protested against strongly, as we wanted experienced men from the start. The result was that Mr. Edwards, a man with some 20 years' experience, was appointed Chief Shop Inspector, and later Mr. Meeser, another experienced inspector, was appointed to assist him. Mr. McLure also spent considerable time assisting Mr. Edwards with the shop inspection before taking up his duties as Inspector of Erection. Mr. McLure also spent the winter months assisting with shop inspection. The inspection on this work was the most thorough of any I have ever witnessed.

Everybody appreciated the magnitude of the work and the great importance of making it to conform to the drawings. With a view of keeping the shop work right up to the highest standard I called Mr. Edwards in the office at different times and requested him to accept nothing but the very best work, and at the same time cautioned both him and Mr. Meeser to always check the measurements with their own private tape, and to the best of my knowledge and belief they did this.

There was never any friction between the Quebec Bridge Co.'s inspectors and our men; all were working to the same end, namely: to make a bridge second to none.

Realizing the absolute importance that every part of this bridge must be right and to impress all the shop men with this fact, I placed notices around the shops, before the actual fabrication of the work commenced, calling their attention to the fact that we were about to start work on what was to be the largest bridge in the world and requested every man to do his best. We put the very best mechanics in the shop on this work; the boring was all done by expert machinists.

I want to say most emphatically, and the actual work will bear out my statements, that we all appreciated the great magnitude of the work and the utmost importance of doing it just right. The way the work went together in the field proves it was right. Everybody who has seen the work does not hesitate to say that it is the very best.

Any tests that were asked for by the Consulting Engineer were always willingly and promptly made and with the greatest care. Together with Messrs. Edwards and Meeser, the Inspectors, and Messrs. Deans and Szlapka, I spent many hours in the testing room witnessing the making of the eyebar tests. We placed our tool-makers at the disposal of the inspectors to check their readings of the vernier calipers. These tests cost a considerable sum.

All the members in this bridge, including the eyebars, were measured by steel tapes standardized by a tape in the possession of Mr. Edwards, the Quebec Bridge Co.'s Chief Inspector, to which were attached spring balances or scales, and 12 lbs. pressure was put on the tape for every measurement made. This insured uniformity of measurements throughout the whole job. The pins for this bridge were forged in the armor-plate forges of the Bethlehem Steel Co., at an extra cost of $20 per ton over and above what we could have purchased ordinary hammer-forged pins for, which would have filled the requirements of the specifications. We all appreciated the great importance of getting the best pin material obtainable, as they had an enormous load to carry, and after many weeks of careful consideration of this particular part of the structure we were instructed to order these pins at this large additional cost, by Mr. David Reeves, President, who from the very beginning said that we must use the best of everything in this bridge, regardless of cost. These instructions have been rigidly lived up to.

In October, 1904, we spliced chords Nos. 1 and 2 of the anchor arm together under the shipping crane in our yard and requested the Consulting Engineer to come to Phoenixville to see how nicely the work went together. After waiting nearly a week he finally came over and was evidently much pleased, as we never heard anything to the contrary. The last week in November of the same year we spliced chords 4 and 5 of the anchor arm together (these are the first two chords that are cambered). After putting on all the splice plates we had our transitman square and level them up with the instruments, then compare them with the drawings, and found them as near to the drawings as it was possible for human hands to make them. We did not complete the splicing of the above chords until late on a Saturday evening and on the following Sunday morning Messrs. Edwards, Szlapka, Scheidl, Wright (Shop Superintendent) and myself, together with a number of others, were there to see whether the work came together as it should, and as stated above, the work was accurate. The next day, and for the next couple of weeks, we made several attempts to get the Consulting Engineer to come to Phoenixville to see these chords, but he positively refused to come. We were very much surprised at this as we were told many times by Messrs. Deans and Szlapka that these cambered chords were probably the most important sections in the bridge and so much depended on having them just right so as to keep the bridge in perfect alinement.

When the first shoe was completed in the shops we assembled both bottom and top pedestal, shoe, chord section No. 11, main post foot, floor beam connections, and all thevarious plates that connected to shoe for brace connections. Again we requested the Consulting Engineer to come to Phoenixville to see for himself how well each part fitted to the other and the excellent work we were doing, but he refused absolutely.

The Consulting Engineer in his testimony speaks of the company being slow in making the special eyebar tests. This was due to the fact that it took considerable time to get the plain bars from the plate mill. After they reached our works it required considerable time to forge, anneal, straighten and bore the bars, and the testing, owing to the numerous measurements that had to be made, was a slow process and required many days.

Mr. Hoare, Chief Engineer of the Quebec Bridge Co., was at the works numerous times during the past four years and always seemed well satisfied with the class of work we were doing for him. At the same time he always kept impressing on us, as well as on the inspectors, the great importance of making everything just right.

Before the main traveler was completely designed for erecting this bridge we made tests of different kinds of anti-friction metals to make sure of getting the very best for the bearings of this traveler, on account of its great weight and the heavy sections it would have to lift. The shackles were made by the best makers in the country and when they arrived here we tested several of them in testing machines. The results were not satisfactory and we refused to accept them and forged them here from solid steel billets. The same care was taken with the false work and travelers, both large and small, as with the bridge proper, and the materials and workmanship were of the very best. Many tests were made of the materials that went into the false-work and travelers, same as were made for the big bridge. Great care was taken to have all sections carefully painted before being shipped or put in storage, and the material in storage has been looked after.

I gave the Quebec bridge material my most careful attention through its various stages in mills and shops, and realizing the great responsibility that naturally was placed upon me as the Works' Manager, I gave up everything in the way of vacations and have been in the works practically every day since we commenced work on the bridge in 1903, except for five days in October, 1905, that I spent going to and at the bridge site in Canada.

*The Quebec Bridge & Railway Co.'s inspectors at Phoenixville.—Ed.

## Testimony of ELLSWORTH L. EDWARDS, Chief Shop Inspector of the Quebec Bridge & Railway Co.

[In Full.]

Mr. Edwards, already referred to in the testimony just preceding, was selected for the position of Shop Inspector by Mr. Theodore Cooper, Consulting Engineer of the Quebec Bridge & Railway Co. This is described in Mr. Cooper's testimony (Engineering News, Oct. 31, 1904, p. 474). He came to the work with many years' experience in bridge shop inspection, and was well and favorably known at the Phoenixville works.

Q. Please file complete list of shop errors detected by the inspectors and indicate those which were specially brought to the notice of Mr. Cooper.

A. Herewith I file with you a book which contains memoranda of all the errors discovered at shops by inspectors. Those marked with an X in red were specially brought to Mr. Cooper's attention, for the most part on the occasions of my frequent visits to his office. Minor errors were sometimes referred to in the course of my conversation with him. Mr. Cooper had advised me to confer with Mr. Szlapka regarding minor errors. This I did, and before the shop was allowed to remedy such errors Mr. Szlapka was consulted. In matters affecting clearances his advice was particularly valuable. My method was to exchange ideas with Mr. Szlapka as to

the remedying of these less important errors and come to a conclusion satisfactory to us both. While such minor errors were not then brought to Mr. Cooper's attention it was my understanding that he approved of this course.

Q. Please file a list of errors which were not detected in the shop inspections and which were subsequently detected and reported from the field.

A. I do not have a complete list of errors found in the field and which were not detected in the shop. Mr. McLure wrote me concerning some of these, but I understand you have this information in detail in his book, labeled "Record of Shop Errors Found in the Field." This record includes the errors of drawings as well as those of shop and a distinction is made between these two classes. As you are probably aware errors of drawings are not chargeable to inspectors, as drawings are supposed to be correct when received by us.

Q. Was every important error that you detected reported to Mr. Cooper and were his instructions in regard to these errors promptly carried out?

A. Every error which I considered of sufficient importance was referred to Mr. Cooper and his instructions were carried out implicitly. Members for the south side were always remedied very promptly. As there was no hurry for those of the north side these were not attended with such promptness but were finally remedied or passed by Mr. Cooper.

Q. Please refer to your letter of Feb. 26, 1906, to Mr. Cooper and explain in detail the conditions you therein described in the second paragraph.

A. In reference to the second paragraph of my letter of Feb. 26, 1906, to Mr. Cooper, I would say that at that particular time there seemed to be an unusual number of errors being made both at the bridge shop and the eyebar plant, and we were endeavoring to get things back to a normal condition. Notwithstanding the efforts being made, errors continued. Such conditions were only temporary and as stated in this same letter "We expect better results before long." And these were obtained. My reference to "being up against a pretty tough proposition" means that new errors were appearing in spite of precautions which were being taken by the Phoenix officials and ourselves. It is my experience that there are occasional short periods when an unusual number of mistakes occur and, vice versa, there are periods when unusually few errors are made.

Q. Within what limits do you consider it practicable to straighten the ribs of bottom chord members, and of the main posts, and how closely can the ribs of consecutive chord members be made to match each other?

A. In reference to the limits considered practicable to straighten ribs I would say that this depends to a large degree on the thickness of these ribs and also the nature of the bend. If the bend is a long curve it is a comparatively easy matter to take out a 3 to 4-in. bend, but if the bend is a short kink this would be a different proposition and could only be decided by the case at issue. However, we are not aware of any chords on the Quebec bridge where it was necessary to remove any short or sharp kinks. Long bends were always removed before milling.

In the matching of consecutive chord members it must be taken into consideration that the web plates may vary in thickness and angles are not always true (viz.: one leg not at exact right angles to the other). Our practice in inspection was to endeavor to have the ribs absolutely the correct distance apart from top to bottom at ends of chords. We did occasionally allow as much as 1/16-in. (maximum). I do not believe it is possible to secure greater accuracy than this where measurements are taken between rolled surfaces.

Q. How closely to true plane will the large rotary planers cut?

A. From actual measurements we know that the accuracy of the milling done by the rotary planer for the larger members of the Quebec Bridge varied from a true plane, where such variation occurred, from 1/64 to 1/32 in. This was the best the machine could do.

Q. We understand that a post section was found 3/64 in. out of true on one corner, and that this was accepted on the ground that the planer could not cut within these limits. Is this correct and was this reported to Mr. Cooper?

A. Regarding main post section found to be out of true 3/64 in. at one corner, the fact of the bearing surface being so great and the unevenness in question being so small and at one point only I deemed it advisable to accept the member, believing that when the weight of the other post sections was on there would be perfect contact. It is a question if any better results would be secured by re-annealing (?) a section so slightly imperfect over so small an area, and by re-milling we would be reducing the thickness of bearing surfaces. This error was not reported to Mr. Cooper so far as I now remember.

Q. Were any full sized tests of plates, angles or built-up members made during the fabrication of the work?

A. Some tests were made of built-up members to represent the ears of posts and hangers. The results of these tests are produced.

No full-size tests of angles or plates were made.

Q. Please file a statement giving the particulars of all full-size eyebar tests and specimen tests of the materials of which they were made.

A. I produce a statement as asked.

Q. State exactly what tests for accuracy were made upon each of the main members and how were these tests made, not only as to dimensions but as to the setting of the pieces in the machine?

A. In reference to tests for accuracy, the facing was first tested with steel straightedge. Dimensions from faced end to center of pin holes were taken by means of a standardized tape secured at one end of member by a stop and supported at points the entire length of piece. To determine the exact center of pin hole, a circular leaden disk was held in place by three set screws and the exact center was established from four points on the bored surface of pin hole. A spring balance was attached to the tape and 12 lbs. tension used in all cases. In measuring distances less than 15 ft. c. to c. of pin holes the centers above described were put in but trammel points were used to check distances in place of tape. Cast-iron gages about 6 ft. long were put in all pin holes. Care was taken to see not only that the pin would enter the hole without difficulty when the member was erected in the field, but that the allowed clearance between pin and hole was not exceeded.

While all holes for splice-plate connections were drilled from iron template, the dimensions between holes were always all carefully measured and in fact this was done in the case of all open holes.

As to the laying out of members and setting same in machine it is not customary for inspectors to check these operations. It is the duty of the shop foreman to attend to such checking, but notwithstanding the custom we did (at Mr. Cooper's suggestion) check the laying out and the boring in many cases in order to reduce the liability of error.

Q. On May 3, 1907, Mr. Hoare asked you for another set of strain sheets for anchor and cantilever arm, and states that he is aware that the strain sheet for the suspended span was not then ready; was there any work on the suspended span at that date in the shops?

A. Yes; the eyebars for the south half of suspended span, about one-half of the material for panel No. 1 south side and some stringers were completed by May 3, 1907.

## Testimony of JOHN STERLING DEANS, Chief Engineer of the Phoenix Bridge Co.

[In Full.]

Mr. Deans, a member of the American Society of Civil Engineers for twenty years, has long been in active charge of the work of the Phoenix Bridge Co. His testimony forms the central feature of the Phoenixville evidence, and describes officially the attitude and actions of the Phoenix Bridge Co. in relation to the construction of the Quebec Bridge. It is kept clear of matters relating directly to general design and detailing, these being treated at length in the testimony following, of Mr. P. L. Szlapka, Designing Engineer, who was in immediate charge of the Quebec Bridge work, and Mr. Charles Scheidl, who was in charge of the detailing. The testimony of these men may be said to form part of that of Mr. Deans as the statement of the contractor for the work.

Q. From whom and at what date did you receive the cross-section of the River St. Lawrence at the bridge site and the other data required for the preparation of the first preliminary plan?

A. On June 16, 1897, Mr. E. A. Hoare wrote to the president of the Phoenix Bridge Co., asking if any engineer of the company expected to attend the annual convention of the American Society of Civil Engineers, which was to convene in Quebec on June 30; if so, he asked that the engineer call to see him, in connection with a project for bridging the St. Lawrence River near Quebec. It was natural that Mr. Hoare should address the Phoenix Bridge Co. in this connection, as about twenty years before, while he was Chief Engineer of the Quebec & Lake St. John Ry., the company had constructed bridges for his road. I attended the convention, and met Mr. Hoare for the first time and also met Mr. Audette, Mr. Boswell, Mr. Dobell, and other directors and officers of the Quebec Bridge Co. Mr. Dobell entertained the entire convention at his home on the St. Lawrence near the bridge site, and during the trip by steamer explained to the engineers present the proposed site of the bridge and the steps the company was taking towards its construction. Mr. Cooper, afterwards Consulting Engineer of the Quebec Bridge Co., was in attendance at this convention and learned of the enterprise at that time. Mr. Hoare said to me on the occasion of this visit to Quebec that if we were interested in the bridge project "I shall be glad to send you a profile of the crossing at the proposed site and other necessary general information so that you may, if you wish, be prepared to bid, if the project is carried out." Shortly thereafter I received from Mr. Hoare the said profile and information.

Q. Please file copies of the outline plans prepared by the Phoenix Bridge Co., dated November 30, 1897, and December 7, 1897, respectively. (Filed.)

Q. Please examine the official plan prepared for the Quebec Bridge Co., dated 13th of January, 1898, and subsequently filed with the Government of Canada, and state if the truss outlines, as shown on it, are identical with those shown on the Phoenix Bridge Co.'s plans, dated 7th December, 1897.

A. I have compared these plans and find that the truss outlines are identical.

Q. Please refer to your letter of November 8, 1897, to E. A. Hoare and state whether or not the general features of the Quebec bridge were determined by the Phoenix Bridge Co.'s engineers?

A. No; except as to the general outlines of trusses and lengths of spans.

Q. Please state why, in advance of the submission of competitive tenders, the Phoenix Bridge Co. allowed its plan for this bridge to become public property by being filed in the Department of Railways and Canals and thus becoming available for use of its competitors.

A. I do not remember that I knew that our preliminary studies of this work, as shown on plans dated December 7, 1897, were incorporated in a plan filed by the Quebec Bridge Co. with the Department of Railways and Canals. Had the Quebec Bridge Co. asked permission to use the plan, I would not have objected. In any case I do not consider the fact of any special significance or as giving our competitors any advantage. At the time tenders were asked, about a year later, bidders had free scope in the matter of design, length of anchor arm, etc., and were asked to bid not only on cantilever span, but on suspension design. As a matter of fact our own tender did not agree exactly with the above preliminary study.

Q. Please refer to your letter of April 14, 1899, to E. A. Hoare and state if you did not understand that economy in design was to be of first importance in arriving at a final choice between competitive tenders?

A. I understood economy in design was of importance, but not of first importance and not to be secured at the expense of any requirement of the specification or of obtaining the most capable contractor for the work.

Q. Was the subsequent letting of various contracts to the Phoenix Bridge Co. in pursuance of the understanding referred to in the letter of April 14, 1899?

A. No. Mr. Cooper reported favorably upon our plan and tender as submitted March 1, 1899, and the contract was awarded to us on this report of Mr. Cooper.

Q. Please refer to your letter of 19th of April, 1899, to E. A. Hoare and state your understanding of the instructions that had been given to Theodore Cooper when that engineer undertook the examination of the competitive designs and tenders?

A. I have read my letter to Mr. Hoare of April 19, 1899. I understood that Mr. Cooper was to recommend for acceptance the lowest and best tender and plan which met every requirement of the specifications.

Q. Did consultations take place between Mr. Cooper and the engineers of the Phoenix Bridge Co. relative to the determination to increase the main span and to the determination of amendments to the specifications, and had these conclusions the approval of the engineers of the Phoenix Bridge Co.?

A. At Mr. Cooper's request Mr. Szlapka had interviews with him at which Mr. Cooper stated that it was proposed to increase the span and amend the specifications. The Phoenix Bridge Co. had nothing to do with the determination of these questions. We were not asked to approve the proposed action.

Q. Did the Phoenix Bridge Co. fully concur in and approve the action of the Quebec Bridge Co., and of the Government of Canada in practically making Mr. Cooper's approval of the plans for the bridge final for all parties?

A. We neither concurred nor dissented. Were not asked to do so. We were bound by the action of the Quebec Bridge Co. and the Government of Canada in making Mr. Cooper's approval of the plans final for all parties.

Q. Did Mr. Cooper suggest to you his inability to continue as Consulting Engineer, and if so when was this, what reasons did he assign, and how did you view his suggestion and with what results?

A. About two or three years ago, Mr. Cooper spoke to me about the possibility of his being unable, owing to illness, to continue his duties as Consulting Engineer and suggested the name of Mr. C. C. Schneider as his successor, should this contingency arise. I told Mr. Cooper that we should consider it unfortunate if a change in authority in the midst of construction occurred and that I hoped and believed he would soon be better and remain through the entire operation. As a matter of fact, Mr. Cooper did improve promptly and as far as I could see was in his usual state of health

and continued his duties in the same manner as previously.

Q. Did the Phoenix Bridge Co. at any time suggest the employment of Mr. Cooper, Mr. Edwards and Mr. McLure in their several capacities?

A. No suggestion of the employment of any of them was made by this company. About the time the necessity of appointing a Consulting Engineer arrived Mr. Hoare said the Quebec Bridge Co. was considering the names of four or five engineers, among them the name of Mr. Cooper, and asked me as to their ability and experience and I said I considered Mr. Cooper the best fitted for the work. We received an application from Mr. McLure for a position. I did not know him, but knowing that Mr. Cooper desired to secure the services of a young graduate of some experience in bridge work, I turned the application over to him.

Q. Do you consider that ample time was given to the study and preparation of the plans? In this connection we understand that the actual weight of the suspended span overran that assumed in the calculations for the anchor and cantilever arms by fully 25%.

A. Yes. Ample time was given. The actual weight of the suspended span did overrun that assumed in the original calculations. The estimated weight was necessarily approximate.

Q. At what date was the first plan approved by the Department of Railways and Canals received by you and what was this plan?

A. The first plan of the main structure, approved by the Department of Railways and Canals, was received by us October 28, 1903; it was the plan of the floor-beam drawing B anchor arm.

Q. Prior to October, 1904, was your office work confined to the anchor arm?

A. No. Prior to October, 1904, our office force was at work on stress sheets of the entire bridge and on the shop details of the approach spans, anchorages and anchor arm.

Q. At what date were the final arrangements made under the contract of June 19, 1903, which permitted you to proceed freely with your work?

A. Feb. 22, 1904. The final arrangements were concluded on this date. We had in the meantime been working on our plans and details of the structure and making provisions for properly and promptly constructing the work.

Q. When you sent the stress sheet of the anchor arm for approval to the Department of Railways and Canals, had you completed your stress sheets for the suspended span and the cantilever arm, and had you designed the traveler?

A. The anchor arm stress sheet was approved by Mr. Cooper June, 1904, and by the Department of Railways and Canals October 11. The traveler was designed April, 1904.

Q. When did you send the stress sheets of the suspended span and cantilever arm for approval and had you then designed the traveler?

A. Stress sheets for suspended span were sent February 19, 1904, and for cantilever arm, May, 1905; the traveler was designed in April, 1904.

Q. After completing the stress sheets of the suspended span and of the cantilever arm and the design of the traveler, did you find that modifications were necessary in the stress sheet of the anchor arm, what were they and did they tend to increase or decrease the stress?

A. Yes. It was found necessary to make modifications in the stress sheet of anchor arm due to increase in weight of suspended span and cantilever arm, but not to the traveler.

Q. Were the members of the anchor arm designed from the stress sheet of October, 1904, which sheet reached the Department of Railways and Canals at the same time as the plans of the details of the bottom chords?

A. Yes.

Q. When the plans for the bottom chords were approved had any of the chords already been built and were they in accordance with the plans as approved?

A. None of the chords were built before Mr. Cooper approved of the plans.

Q. Was any work done or material ordered prior to receipt of approved plans from the Department of Railways and Canals, and if so give details.

A. Yes. Work was done in many instances including anchor arm chords and other members upon receipt of plans approved by Mr. Cooper and before the plans were actually approved by the Government, as Mr. Cooper's approval was final as far as we were concerned. No changes were ever made by the Government on any plans approved by Mr. Cooper.

Q. The contract between the Phoenix Bridge Co. and the Quebec Bridge Co. provided for payment at prices per pound of material erected complete. Was there any limit at all placed upon your company as to the amount of money the bridge should not exceed in cost, or was any sum mentioned to you that it would not exceed?

A. No.

Q. What financial considerations governed you in the design of the structure?

A. We were not governed by any financial consideration in connection with the design of the structure.

Q. Did the Consulting Engineer at any time urge upon you the necessity of economy, beyond the point where you considered the best efficiency could be obtained?

A. He effected economy in cost by changing the specifications, and these changes lowered the efficiency of the bridge. In details not expressly covered by the specifications he also exercised economy. He endeavored to reach an economical design, and we did not think he carried this so far as to lead us to question the safety of the structure.

Q. Did any one else?

A. No.

Q. Have you and your staff acted harmoniously with Mr. Cooper throughout this work?

A. Yes.

Q. Did the changes in unit stresses meet with your approval?

A. The changes in unit stresses were made by Mr. Cooper and were not submitted to us for our approval. Mr. Cooper merely talked the matter over with Mr. Szlapka as a brother engineer, but not, however, for the purpose of getting the wishes of the Phoenix Bridge Co. He then reached a decision of which we were notified and upon which we acted.

Q. Did these changes follow previous experience, or did they take the work out of the field of past experience in bridge construction and detailing and in what respect?

A. The changes in unit stresses for compression members carried them out of the field of past experience in bridge construction and detailing and did not follow usual practice.

Q. Do you consider, in view of this, that enough time and study were devoted to the preparation of designs?

A. Yes. We took all the time considered necessary for the study and preparation of plans, and I believe Mr. Cooper's office also took all the time that they considered necessary.

Q. To your personal knowledge, was Mr. Cooper's examination and criticism of plans aggressive and did he insist on discussion of all matters in which questions arose?

A. Yes. The examination of details and plans by Mr. Cooper's office, I believe, was conscientiously and carefully done. Discussions often arose, but Mr. Cooper's decision always prevailed.

Q. Were all plans to your knowledge approved by the Consulting Engineer?

A. Yes.

Q. In any instance were plans sent to the Phoenix Iron Company before the approval of the Consulting Engineer was obtained and was any fabrication commenced prior to such approval?

A. In a few instances and late in the work, plans were sent to the shops for preliminary work before the actual approval by the Consulting Engineer; so that we would be prepared to carry on the work promptly. This was done only in the case of plans of which the design and detail had already been established and approved by the Consulting Engineer. We took the risk of possible alterations by him. But in no instance was a single member of the bridge actually completed which was not in accordance with the final approved plans.

Q. Was the design of details of the lower chord discussed with Mr. Cooper and was his opinion specifically obtained on the latticing and other details and, if so, please state fully what took place?

A. Yes. I had no interview with Mr. Cooper on this subject, but I instructed our Designing Engineer particularly to submit the question of size of latticing of chords to Mr. Cooper. Mr. Szlapka later reported to me that he had an interview with Mr. Cooper on this point and Mr. Cooper advised him that the lattice angles were correct as shown on approved plans. Mr. Szlapka will give you the details of his interview with Mr. Cooper on this point.

Q. We understand that the Phoenix Bridge Co. maintained an independent inspection of the shop work done by the Phoenix Bridge Co. Please file a copy of the record of the errors detected by your inspector.

A. An independent inspection was maintained and I herewith submit the daily record. Every error, however small, is noted in that book and all these errors were corrected before the work left the shop.

Q. Were all errors reported satisfactorily corrected by the Phoenix Iron Company?

A. Yes.

Q. What precautions were taken to insure the safety of the bridge members in handling and in transportation? What measurements were made at the bridge site to detect distortion or injuries occurring to members in transit?

A. Special precautions were taken to insure the safety of the bridge members during handling in transportation. We consulted with the Superintendent of Motive Power of the Pennsylvania R. R. Co. and devised with his representative special schemes of loading. All large and heavy pieces were the subject of special consideration with the transportation companies. All members were carefully inspected as to distortion and injury during transit, after the members arrived at bridge site and before they were erected in place. I cannot say just what measurements were made in the course of this inspection. This inspection was by the representatives of both the Quebec Bridge & Railway Co. and the Phoenix Bridge Co.

Q. Please file a full list of all members injured in handling or in transit with a statement of what subsequent action was taken in each?

A. Only one member was injured in transit, being the shell frame south anchorage. The repairs to this member were explained in detail in the evidence of Mr. A. B. Milliken. One member was injured in handling at south storage yard, being chord 9 L anchor arm, repairs of which have been covered fully in evidence. One member was dropped in handling in the shops, slightly injuring it and one or two other smaller members. Thorough repairs were made, all as shown in detail in the shop inspector's report. These members were thoroughly repaired under the direction and to the satisfaction of the inspectors.

Q. Please file a complete list of "field corrections" reported from the bridge site. (Filed.)

Q. Please file a statement compiled from your weekly records showing the weight removed from and added to the cantilever arm and suspended span during 1907. (Filed.)

Q. Please give a statement with dates complete showing fully Mr. Birks' experience and the nature of the work upon which he had been employed.

A. A statement of Mr. Birks' experience in no sense conveys a proper estimate of his ability, which was unusual for a man of his years. He was specially fitted by character and temperament for the work entrusted to him. His experience was as follows:

On March 22, 1902, we received a letter from George F. Swain, Professor of Civil Engineering at Massachusetts Institute of Technology, Boston, suggesting the name of A. H. Birks to us as a desirable man for our engineering department. He wrote as follows: "I also have an exceedingly good man who graduated in architectural engineering and has been taking a post-graduate course with me. His name is A. H. Birks. Birks is a man of exceptional ability in this line and having taken all my work in structures is well up in bridge work as building work. He has also had some experience, having worked one summer with a bridge company and one year in an architect's office, I believe. He is an exceptional man."

We gave Mr. Birks a position and he started to work in our drafting department and worked there for about six months. We soon found he had traits of character and ability that would fit him well for erection work, and he was transferred to the erection department October 7, 1902.

Between October 7, 1902, and November 8, 1902, he was in the field on erection of plate-girder spans, N. & W. Bridge, Circleville, O. December 1, 1902, to June 15, 1903, on Central R. R. of N. J. bridges, Wheelers Lock, Parryville, and Glen Onoko (plate-girder structures) and Lehigh River Bridge, Parryville (through riveted spans), June 18, 1903, to August 13, 1903, Southern Ry. bridges, Caswell, Tenn., Mascot, Tenn., Knoxville, Tenn., Alexandria, N. C., Wolf Creek, Tenn. Jefferson City (all plate-girder spans) and Tennessee River Bridge, Straw Plains, Tenn., 105 ft. (deck plate-girder structure). February 11, 1904, and during the month he was Inspector on Southern Ry. bridges—James River Bridge, Lynchburg, Buffalo River Bridge, Rappahannock River Bridge (all through truss bridges). July 24, 1904, to Aug. 3, 1904, at Deepwater, French Broad River, Hot Springs, N. C., 264 ft. (through pin span) during the erection of the trusses. In March, 1905, Jacksonville, Fla., examining sites of two Atlantic Coast Line R. R. draw bridges, securing necessary information for preparing erection plans. February, 1906, New London, Conn., arranging method of erecting Jordan Cove Bridge. During the intervals not covered by above, Mr. Birks was engaged on erection plans and details in the office at Phoenixville.

When the Quebec erection was taken up early in 1904, Mr. Birks assisted in all the preliminary studies and continued on this work until the entire plan was fully developed and settled upon. Many of the features of this erection scheme which worked out so successfully in practice were due to Mr. Birks' peculiar ability in this line. His familiarity with every detail of the erection scheme and the behavior of the trusses during erection, his thorough technical training, his absolute reliability, decided us to appoint him Resident Engineer of the erection and he was sent to Quebec in September, 1904. He was on the work during the working season from that time until the date of the disaster, with the exception of the period during the erection of the main traveler, when Mr. C. W. Hudson was resident engineer.

Mr. Birks was fearless and was able to climb over the entire structure. He had a lovable character and that about him which instantly demanded respect and confidence. He could have his orders carried out readily without friction. It would be difficult to find a man combining the many traits of mind and character which so eminently fitted him for the position of resident engineer of erection.

Q. Please file a detailed statement of all the long span bridges that have been built by the Phoenix Bridge Co. since 1890.

A. The Phoenixville Bridge Works have constructed since 1865 about 610,000 tons of bridge work. They are the pioneers in bridge construction in the United States. Among the larger works constructed by them we mention the following:

Pecos Viaduct, Texas, Southern Pacific Ry., 2,080 ft. long, 326 ft. high (1869).

Ohio River bridge, Cincinnati, O., C. & O. Ry., one and one-half miles long, containing 550 ft. through pin span, the longest and heaviest truss constructed (1888).

Harlem River Draw, New York City, 303 ft. through riveted. Turntable 60 ft. diameter, largest in the world (1896).

Red Rock Cantilever, Santa Fe R. R., 660 ft. central span (1890).

Mississippi River Bridge, Rock Island, Ill., for United States Government. A double deck structure, 1,850 ft. long (1896).

Cambridge Bridge, Boston, Mass., 11 plate arch spans, weight 16,000,000 lbs. (1904).

Omaha draw, 520 ft. through pin (1893).

Sioux City Bridge, Nebraska, two 470 ft. draw spans, two 500 ft. through spans, 4,000 tons (1896).

Manhattan Bridge, New York, 1,470 ft. central span, 725 ft. side spans, 34,000 tons (not including cables) (1906-07).

Q. Why were Mr. Cooper's suggestions of August 9, 1907, for the repairs of the splices at 7 L and 8 L cantilever arm, not adopted and promptly executed?

A. After the lower chords, including the details of shop and field splices, were approved by the Consulting Engineer, the engineers of the Phoenix Bridge Co. and the Erection Department carefully considered the action of the field splices during connection of trusses and the camber movement of splices while members were receiving their full dead load. A special camber blocking was designed and placed on falsework under each panel point. This blocking was easily adjusted and free to move longitudinally. Special consideration was given to the bolting before the riveting of splices. Full instructions were prepared in advance of erection and incorporated in a blueprint book of instructions to the field force. The bolting was checked in person by the Resident Engineer and regular reports sent to Phoenixville. The action of the joints was noted and reported on printed forms as erection proceeded, by the Resident Engineer in charge of field instrument work. The action of joints was also noted specially by the Designing Engineer and Assistant Engineer in charge of details during several visits to the bridge site. All of this was in addition to the regular erection supervision by the general foreman and his assistants. The splices were under the closest scrutiny at all times and they acted as expected in closing to complete contact. No report was received at Phoenixville advising us of anything wrong in connection with any splice until August 8, 1907, in a letter from Mr. Birks, dated bridge site, Aug. 6, 1907. In this letter he advised us that one of the inside ribs at bottom of splice chord 7 L—8 L, cantilever arm, was bent out of line and enclosed a sketch of a diaphragm to be riveted between the ribs to hold them in their position. This proposed diaphragm was sent to Mr. Cooper by Mr. McLure on same date as it was sent to us, but he did not approve it—see telegram from him August 8, 1907. Mr. Cooper never gave us any instructions concerning the matter. His letter of August 9 simply deals with ideas and you will notice by his letter of August 13 that he desired before acting to get further information from his Resident Engineer, Mr. McLure. His letter of August 21 indicates that he had not yet reached a decision and the matter was still in this unsettled state when the accident occurred. There were no joints in the anchor arm where similar bend in rib was noticed, they all lined up true and satisfactorily.

Q. Were Chords 9 L, anchor arm, and 9 R and 8 R, cantilever arm, in perfect condition when they left Phoenixville?

A. Yes.

Q. Were requests and suggestions made by Mr. Cooper with regard to tests, and to matters of erection always promptly considered and, when acted upon, was it with all possible promptness, giving specific instances?

A. Yes. As instances: Special tests of eyebars in connection with deformation of eyes; water-gage levels for use at bridge site; investigation of top section of main post by Mr. Scheidl.

Q. What is your opinion concerning the movements of the bridge when falling?

A. The position of the wreckage indicates to my mind that a compression member, a lower chord in anchor arm downstream truss, failed first and, immediately following, the compression member directly opposite failed. The failure of these two compression members permitted the anchor arm to move two panels toward the river. The lower chord of cantilever arm being relieved of support forced the two shoes towards shore and broke off a lower section of main post. The downstream chord anchor arm failing first permitted the truss to drop vertically as well as horizontally and had a tendency to pull the higher parts of the superstructure down stream. The pinnacles at the top of main post are pointed in this direction.

Q. Please explain the references in Mr. Birks' letter of August 29, 1907, with regard to the telephone conversation about stopping the work of erection.

A. On August 29, 1907, we first learned from the letter of August 27 from Mr. Yenser that buckles were noticed in webs of lower chord 9 L of anchor arm. Consultation then took place at Phoenixville between the engineers, shop officials and inspectors, and it was determined that chord could not be bending from any excessive stress, as it was carrying only three quarters of the working load for which it was designed and approved. We then called Mr. Yenser and Mr. Birks on the 'phone and advised them of our conclusion. During this conversation on the 'phone they notified us that a portion of the bends had been in the webs for a long time. That since writing on August 27 they had carefully watched and repeatedly examined the chords and found there was no further movement, and that they had proceeded with the erection without waiting for advice from us. As this action agreed with our own conclusion we told them we thought they had acted wisely in not stopping the erection. Mr. Birks' letter refers to this 'phone conversation. While a chord with bent webs, even though bends are slight, is not capable of performing its functions as well as a perfectly straight member, the bends in chord 9 L noted on August 27, and of which we learned on August 29, were not such as to shake absolute confidence of years which all had in the entire structure. If the consulting engineer then believed there was imminent danger and that all work should be stopped immediately, it was not necessary to inquire whether Mr. A. B. Milliken was at site or not. Mr. Hoare had sent Mr. McLure to Mr. Cooper to report on the bends in chord 9 L and to receive his advice. Mr. Hoare was in Quebec and any message to him would have stopped the work instantly, as was done on a previous occasion by direction of Mr. Cooper. The testimony of others shows that Mr. Cooper on August 29 no doubt had no thought of imminent danger. We all now see, what no one dreamed of before, that the compression chords were beyond any scheme of protection on August 29 and were failing under less than half the load for which they were designed and approved and were considered capable of sustaining without failure. While it is difficult it is essential, in order to reach an accurate judgment, to keep in view the frame of mind every one was in before August 29 regarding this structure and its strength and the respect and confidence all had in the engineers responsible for its design and detail.

Q. Was the bridge in all particulars designed by the engineers of the Phoenix Bridge Co. and were these designs fully approved by the Quebec Bridge Co. through their consulting engineer, Mr. Cooper?

A. The bridge was designed in its general features by the engineers of the Phoenix Bridge Co. The details of the bridge were worked out in connection with the Consulting Engineer, to agree with the modified specifications which he had prepared, and all plans and details were approved by the Consulting Engineer, Mr. Cooper.

Q. Please file the reports showing the condition of the joints in November, 1906, and also a similar report to August 29, 1907. At what date was the joint 8-9 L anchor arm riveted?

A. Reports herewith show the condition of joints November, 1906, and also a similar report of August 29, 1907. Joint 8-9 L anchor arm was riveted June, 1907.

Q. The contract for the main spans was signed June 18, 1903, and called for the completion of the work by December 31, 1906. Was the time allowed, in your judgment, sufficient for the satisfactory carrying out of the work? Did Mr. Cooper express any opinion to you concerning this?

A. The time for completion in our contract of June, 1903, was given as December 31, 1906, and was fixed by the Quebec Bridge Co. We believed this time was too short and would not agree to be bound by it, and on the date the contract was executed letters, which have been submitted to you, passed betwen the two companies extending the time to Dec. 31, 1908. Mr. Cooper subsequently expressed his opinion in this connection saying four or possibly five years would be required for the construction of the bridge, this long time being required because of the short working season for erection, and not because of other construction demands. As a matter of fact the Phoenix Bridge Co. was unable to start on the work as early as had been expected because of the delay in the completion of the south approach to the bridge, and hence notwithstanding due diligence on its part the work could not have been completed for some time after December 31, 1908.

Q. Please state the circumstances that called for the letter to you from Mr. E. A. Hoare, dated October 20, 1906?

A. Mr. Hoare's letter of October 20, 1906, was called forth by correspondence I had with Mr. Milliken in connection with the demand which Mr. McLure had made to him to stop certain work on falsework of south anchor arm, after Mr. Milliken had received instructions from me over the 'phone to proceed with this work at once. It was work which demanded prompt attention and was not of such an important character as to call for action on the part of the consulting engineer; and while it was a change from our original printed instructions, it was only such a change as might be looked for in work of this character. Mr. McLure was fully informed of all our erection methods, etc. In this particular instance there was no opportunity to advise Mr. McLure in advance. Mr. McLure or any other representative of the Quebec Bridge Co. could have had the work stopped by communicating with his superiors. The correspondence which you have will give you further details.

Q. Is there any known system of bridge erection that could eliminate or modify the camber system adopted by you in the erection of the Quebec bridge, and was the system adopted by you after careful study and calculation, the proper mechanical method to adopt?

A. I know of no system of erection of a stiff frame which can be carried out without some form of a camber system. It is a mechanical necessity. This system has been used with success from the beginning of bridge construction, and in the Quebec Bridge was worked out in greater detail than ever before. A special camber blocking at each panel point enabled us to keep the work in absolute control. As the dead load was applied and changes in anchor frame were taking place, the action of all joints was watched and reported and we found that the truss was behaving exactly as expected and it continued to do so up to the time when all joints had a full and complete bearing.

Q. Is a statement that the Phoenix Bridge Co. had promised both the Quebec Bridge Co. and the Dominion Government to complete the bridge in 1908 and was therefore pressing the work with all speed consistent with safety, a correct statement of facts?

A. The Phoenix Bridge Co., when asked at the time of signing the contract and later, assured the Quebec Bridge Co. and the Government that it would use every effort to complete the bridge within the contract period, but no promise was made to do so.

Q. Please state what technical knowledge of permanent value to the engineering profession has been obtained in connection with the construction of the Quebec bridge?

A. It is too soon to give in any proper manner the "technical knowledge of permanent value to the engineering profession" which will grow out of the construction of the Quebec Bridge and the disaster of August 29.

Q. We understand that the bridge was struck by lightning on more than one occasion. Will you please say what effects were observed due to lightning and do you connect them in any way with subsequent events?

A. During the construction of the work lightning struck the wooden derrick at top of main traveler, destroying the mast but doing no other damage. Lightning also struck the end of the traveler which was raising falsework on north side, damaging the end of traveler only. These two occurrences had no connection with subsequent events.

Q. Did you interest yourself in any way at any time, and when, in any attempt to negotiate or dispose of securities of the Quebec Bridge Co., and with what result?

A. At their request we introduced the officers of the Quebec Bridge Co. to bankers in this country. At the time the Quebec Bridge Co. desired to dispose of their securities. Nothing definite came out of these negotiations.

Q. What was the reason for the failure of these negotiations, and what reasons did the parties give for not taking up the project?

A. As I remember, the experts of the bankers reported at that time that they did not find a sufficient possible traffic in the near future to pay interest on the bonds. They all expressed their belief in the ultimate value of the property, but the returns were too remote for bankers in this country.

Q. Did you fully consider the Quebec Bridge Co.'s project at this time from a business standpoint and did you approve it after you had made your investigation?

A. At the earliest date I had personal confidence in the Quebec Bridge Company's project and strongly approved of it to the officers and directors of my company.

Q. Was the executive work in the negotiating and

carrying out of the contract done by you on the part of the Phoenix Bridge Co.?

A. The executive work in connection with the negotiations and carrying out of the contract was done by me.

Q. In your negotiations with the Quebec Bridge Co. did you find that all matters were conducted on a purely business basis?

A. In all negotiations with the Quebec Bridge Co. all matters were conducted on a purely straight, business basis.

Q. Did you receive any favors over your competitors?

A. No.

## Testimony of CHARLES SCHEIDL, Assistant Engineer of the Phoenix Bridge Co.

[Substantially in Full.]

The course of the detail designing of the Quebec Bridge is fully outlined in the testimony of Mr. Scheidl, the Assistant Engineer in charge of this work. This narrative has perhaps less relation to the collapse of the bridge than the testimony of the other witnesses, but it is of very high interest in bringing before the mind the great intricacy of the work described and indicating the care and thought bestowed upon it. It helps to explain the fact noted by all those who examined the wreckage of the bridge, namely that all joints and connections—except, perhaps, the chord splices—exhibited a wonderful degree of resistance, and in most cases, indeed, stood the fall without injury. Mr. Scheidl and his immediate superior, Mr. Szlapka, are responsible for the character of the details. Both have been in the employ of the Phoenix Bridge Company for many years. Mr. Scheidl came to Phoenixville in 1883, after four years engineering work in Germany and America, preceded by a course in a German technical college. He was placed in charge of the drafting work of the Phoenix Bridge Company in 1889, and has held this position since then.

The examination of Mr. Scheidl was not put in the form of specific questions, but for convenience he was allowed to prepare a connected statement of his part of the work on an understanding with the Commission as to the scope of the statement.

I. PRELIMINARY OFFICE WORK.—The first step in connection with the detail work for this structure was to go over the outlines of the bridge, at the same time looking over the general stress sheets. The first thought was: How will the suspended span be connected to cantilever, how supported by it, and is it to swing free at one or both ends? Next my thoughts were given to details of shoes for main posts and then follow the anchorages. In building this structure one naturally had to find first the manufacturing limits of existing bridge plants regarding:

1. Tension members.—It had been decided to use 15-in. eye-bars as best suited for this bridge and it was found that a 12-in. round pin was the limit at that time on account of the large size of such eyebar heads. Yet it was known that the top chord of anchor and cantilever arms must be composed of a broad chain of eyebars of dimensions hardly ever used before. The packing of top chord eyebars had, therefore, to be so arranged that a 12-in. round pin would satisfy all the requirements of the specifications, while for built-up members any size of pin could be used.

2. Compression members.—The building of compression members seemed at first to involve no difficulty whatever, but as soon as some of the connections had been studied it was found that more than one pin at a panel point must be used for any successful detail and for safe erection, and the question of links presented itself at once. Through the attachment of links for eyebar connections these compression members assumed such dimensions that the question of transportation became a most important consideration. The carrying loads and clearances of the different railway companies transporting material to Quebec had to be studied before any large compression member could be detailed.

Returning to the detailing of suspended span, one end had been arranged fixed while the other end moved on a nest of rollers. This roller arrangement caused a bulky detail at end of cantilever, besides which the end posts of suspended span could not be braced properly near the floor line. Moreover, great difficulty was experienced from the eccentric loading in a longitudinal direction, caused by the movements principally due to temperature, but also due to deflection of trusses, which movement might have been further increased by some slight error in not building main piers 1,800 ft. c. to c. This movement amounted to about 2 ft. Finally, the erection of such a roller end would have involved additional difficulties and it was found that the use of swinging end posts would give the best results.

The next question was how to provide for the transfer of wind stresses from suspended span to cantilever arm. Such a transfer was made at first in the four bottom chord ends of suspended span, but this scheme had to be abandoned because of the difficulty of making these arrangements in both trusses work simultaneously. Finally, a design with only one transfer of wind stresses per span end was decided upon as it gave safe and determinate results.

All the different panel points of the suspended span were now detailed, and exact pin packings made, etc. This suspended span, though larger than ordinary long spans, presented no special difficulty. The erection problem could at this time be gone over only in a general way.

The details for the suspended span were those generally used. The details at intersections of top of hangers and top of sub-posts were first tried with one pin, but the connections made the one pin very long and the connected members had undesirable, long, weak jaws, while with the introduction of links the hanger and sub-verticals could be connected in a most satisfactory and substantial manner to the transverse bracing, giving greater stiffness. Besides, the difficulties of erection were reduced, as otherwise the traveler would have had a much greater overhang and this would not only have increased the weight of the traveler, but also the weight of the structure. It was the intention at this stage to try some toggle arrangements for adjusting suspended span halves during erection.

The next study was that of the arrangement of the top chord packing for cantilever and anchor arms. Links fast to posts for diagonal eyebars were deemed necessary. The question of using two pins for top chord connections at main post of cantilever also arose and it was proposed to use only one pin at these apices. The details of the principal panel connections were drawn out next. The links for connection at bottom end of diagonal eyebars were first designed fast to bottom chord as being more desirable and smaller in size, but this scheme had to be given up as the connections of floor beams to post and bottom chords came weaker, while links fast to posts gave a splendid connection between floor beams and posts. This obviated the necessity of having end stiffeners on floor beams shipped loose as depths of floor beams exceeded shipping limits. After all these apices had been sketched out and the packing plans for trusses completed, the main shoes and main posts were gone into. Extraordinary dimensions were required for the pedestals under the main shoes to properly distribute such an enormous weight over the masonry. The original idea was to build each tier of pedestals in one piece, but shipping limits forbade this and special milling machines had to be constructed. The shoe had been so designed that all loads passed through its pin, but the scheme of letting the main post bear directly on the pedestals while shear from bottom chords only passed through shoe pin was considered too. Special attention had been given to transferring all wind loads collecting near shoe into masonry. The detail at top of main post was at first tried with one pin, but two pins were found necessary. The main post had been so designed that the placing of its ribs gave the best resistance to bending of that part of post where transverse bracing had to be omitted for passage of trains and wagons, while ribs of posts near top and bottom had to be placed in a longitudinal direction.

The details for connection of top laterals, top transverse strut and top chord should be specially mentioned as many devices were sketched out before a selection was made.

The anchorages had already been built with a liberal allowance at that time for any increase of uplift and also the two 214-ft. approach spans had been built. These items require no special notice here. All this preliminary work had been done during January, February and March, 1902, by myself, and I was always in charge of all detail work of this bridge.

II. PRELIMINARY DETAILING.—After the receipt of the revised specifications preliminary work, showing practically final results, commenced in July, 1903.

The first step was to determine normal lengths of all bridge members. As trusses had not a single horizontal member, all inclined members were designated by ordinates and co-ordinates expressed exact in feet and inches. The elevation of any panel point could quickly be checked without knowing the length of any inclined member. Next in order, preliminary drawings of all plate and trussed floor beams and of all stringers were made and sent for approval. The execution of these floor beams and stringers was most elaborate with reference to the spacing of rivets in webs and covers, taking care of end shear, net sections, etc. Then, details showing type of transverse bracing were made for approval; also, details showing very clearly main shoes, pedestals, connecting chords, and bracing of same.

The arrangement of eyebars for the anchor arm required considerable time and study, as the bending moments on pins had not to exceed the allowed values of a 12-in round pin. After some packings had been arranged and the problem of manufacture studied carefully, the final decision was to have no eyebars thinner than 1¼ ins., nor thicker than 2 1-16 ins. To avoid additional stresses on eyebars the skew in regard to center line of trusses had not to exceed 4 ins. in 50 ft. If the skew could not be kept within that limit on account of clearances for bridge, eyebars were bored skew to eliminate additional stresses in eyebars and the method of marking such eyebars was most distinct and precise so as to make sure that any such bars would not be placed the wrong way in the bridge. The sides of these eyebars were marked before being removed from the boring machine and the heads were painted "Inside" and "Outside" with different colors. It is needless to say that the calculations for packing all top chord eyebars was a most tedious and time-swallowing operation.

In all cases the desire was to avoid difficult calculations by placing eyebars so that moments could be reduced to zero as often as possible. All eyebars were so grouped and ribs of chords were so divided as to get 2, 3, 4, or 5 (or even half sets) equal sets; in other words, all ribs at connections were packed alike, and, therefore, stressed alike. In all top chords the stresses coming from diagonals were counterbalanced by eyebars in chords placed so that this transfer was practically direct, while the rest of the chord eyebars, getting their stresses from former panel points, were side lined.

The details for anchorages were worked out next. The method of transferring wind shear at end of anchor arm to masonry had been made through checks between end floor beams and top strut of wind bent. The uplift caused from wind had been taken care of by means of long foundation bolts. This wind uplift was finally ordered to be taken care of by the main anchor bars themselves, and only the horizontal transverse shear was resisted by foundation bolts. The transferring of wind stress from end of anchor arm to top strut of wind bent was finally accomplished by means of a tenon girder which had a roller bearing against top strut of wind bent, and could move in any direction, whether the movement was caused by temperature or by change in the loading of the bridge.

The lengths of all stringers were determined, then, by calculating the length of chords for all the different ways of loading and finding therefrom the lengths of stringers according to their elevation between chords. These stringer lengths were fixed so as to give the least bending in floorbeams. The result was that every other panel had an expansion joint. At expansion joints the railway stringers only were fast to the floorbeams on one side, while all other stringers were slightly loose so that bending of floorbeams could not take place in the short distance between chords and nearest stringer.

At this stage the preliminary detail of all anchor arm panel points was started, commencing with the end bottom chord. All these plans were made in a most elaborate manner; all stresses, pin bearings, number of rivets, calculations for each, etc., were clearly given on each drawing. All ribs of chords were so arranged as to divide each truss connection into two, three, four or five equal ribs, so that each got its proper share from diagonals; in other words, all roundabout connections were avoided to secure the simplest and most direct connection in all cases.

Though all main posts consisted of only two ribs, the ends had to be provided with four or more ribs for proper chord connection. At bottom of posts the floorbeam shear was transferred to all four ribs in the most direct manner.

Sub-posts and hangers were built of only two ribs throughout, but where they were connected, for instance, to a four-rib detail, each rib got quarter of the stress in vertical and horizontal direction. Wherever additional ribs and posts were placed all such connections fully provided for shear, chord stresses, etc. The bearing values on pins had been made 1½ times the allowed stress, but this was later changed to 1¼ times the allowed stress. Shear on pins was made ⅝ times the allowed stress. The net section through pin-hole was made first 1¼ times and later 1.3 times the net section of member, while the net section back of pin-holes was made ⅝ of that through pin-hole. In determining net sections through pin-holes not only rivets directly opposite pin were considered, but the placing of any rivets in such links was most carefully followed throughout. The net sections of all riveted tension members were found by assuming the rupture to take place through any diagonal line of rivet holes where the net section does not exceed by 30% the net section of the transverse line. All panel points of anchor arm had been sketched out in the most studious way. Most points were shown giving several ways of making the connections until a final one had been selected. As these sheets showed not only every detail,

but all the calculation throughout, it was an easy matter for any draftsman to make final shop drawings therefrom in a most intelligent manner. Neither pains nor time were spared in any of these preliminary details, for the anchor and cantilever arms and suspended span. Every detail had been clearly demonstrated in every conceivable manner before shop drawings were made; in fact, many of the draftsmen became disgusted with the never-ending trials to improve these details. When the details for anchor arm were completed and those for the cantilever arm partially completed the weights of all details were calculated by the computing department and final anchor arm stress sheets furnished.

This was the beginning of the shop drawing period. Only the anchor towers had been shop detailed in the meantime, as sketched out some time previously.

III. SHOP DRAWING WORK.—Before commencing the shop work on the anchor arm a clear understanding with the Erection Department had to be arrived at as to where the field splices had to be finally placed. As an overhead traveler, running on falsework and straddling both anchor arm trusses was provided for, the erection problem of the anchor arm was simplified as far as the office work was concerned. The work of getting out shop drawings for the larger traveler and steel falsework had been assigned to two other assistant engineers.

For the cantilever arm and suspended span complete plans were got out showing the location of splices, the number of each piece in the order in which it was to be erected, temporary rods and struts and support of large traveler. A special drawing had been made for each position of the large or small traveler, and these drawings formed a binding contract between the Drafting Office and Erection Department. Before any shop drawing of the larger pieces could be made, sketches giving the extreme dimensions, weight, etc., had to be made for the different railroad companies. This took considerable time, as these companies had not only to determine if these large pieces could be shipped over their own lines, but if they could be shipped the whole distance from shop to bridge site. Such sketches were, in many cases, quite extensive drawings requiring much time in the office for preparation and often showing special beams, struts, castings, pins, etc., to rig up cars, without reference at all to the work in this line usually done by the shipping department. It was necessary to provide for the proper distribution of loads between sets of wheels and to lay out railroad curves so as to make sure that links on posts, etc., placed in special well cars would not touch the wheels or be otherwise injured on sharp curves.

The normal condition of truss shape had been fixed for a certain position of live-load giving practically the maximum uplift and all cambers were derived therefrom. All angles and abutting splices were figured for this position so as to be sure that under full loading any extra initial stress would equal zero.

Pin-holes for 10½, 12, and 14-in. pins were bored 3-64 in. larger than size of pin.

Pin-holes for 24-in. pins were bored 1-16 in. larger than size of pin.

Pin-holes for 7 11-16-in. pins were bored 1-32 in. larger than size of pin.

Pin-holes for 2 5-16-in. pins were bored 1-50 in. larger than size of pin.

In determining the length of eyebars the first correction was for camber, the second for permanent set, the third correction was on account of play in pin-holes and in eyebars placed skew the fourth correction was for skew. The permanent set in eyebars was determined by a series of tests. The correction for permanent set in anchor eyebars was 3-64 in. per head, while for the rest of the bridge 1-32 in. only was used, as the eyebars were finally made of a higher ultimate steel. The correction in built lengths was 1-32 in. for each eye.

All posts with link attachments involved additional work in determining the lengths as the exact position of pin in pin-hole for chord connection had to be found first, and correction in all directions was made therefrom. In all cases the distances c. to c. of pins represented the lengths of members and not the distances c. to c. of pin-holes. In posts with links the eye connecting to chords had to fulfill all the requirements of a regular tension link to suit the resultant stresses of chords.

All rivets were determined by these values:

For shop rivets, 1.5 times allowed stress for bearing value; 0.75 times allowed stress for shear.

For field rivets, 1.1 times the allowed stress for bearing value; 0.55 time the allowed stress for shear.

To get the proper elevation of bottom chord for erection purposes the deformation of the anchor arm was found according to Williott's method. It was assumed at first that the main post was plumb and that the whole anchor truss rotated around the pin of the main shoe until the end bottom chord pin could be connected to the top of anchor eyebars. For this purpose a rotation diagram was constructed which gave the location of every apex after rotating the truss. For the purpose of jacking up the trusses special jacking blocks were provided for two 500-ton jacks per panel point.

To get deformation diagram in the most exact manner all the vertical members had to be corrected again for compression, as they carry heavy top loads during erection, while for all diagonals and chords a position for pins in pin-holes had been assumed which seemed most probable.

As the bottom chord is 4½ ft. deep the abutting splice ends could not fit exactly as they were designed to fit perfectly under full load. Therefore, these differences had to be calculated and ¼ of the amount considered as an increase in chord length. These openings were intentionally made only half the amount that had been figured. In like manner the deformation of trusses was found for any position of the traveler on the cantilever arm or suspended span; also, for final position under dead-load, dead-load + live-load, and according to temperature. The result was that the horizontal movement due to temperature was the greatest, the changes from dead-load or live-load seemed small and the vertical movements did not affect the detailing to any appreciable extent.

For erection of cantilevers the tops of main posts were provided with two pins giving an improved and safer method of erection.

For adjusting suspended span halves during erection two 1,250-ton jacks were provided at each end of bottom chord. For the same purpose a toggle arrangement worked by two 500-ton jacks was provided at each end top chord of cantilever. The bottom panels of suspended span half to be erected last were built of eyebars, while all other chords had to be of built section. By means of this arrangement the bottom chord could be erected completely, although the end distance was too little, as truss halves were jacked up and no fine adjustment would have been required. The last diagonal of suspended span had a special pin connection for quick connection, although the joint was to be a riveted one finally. The details of the suspended span were still further improved by making most of the joints riveted connections. Of course, diagonal eyebars were connected by pins. This method simplified the erection. As soon as two members had been erected final connection could be made and they were self-sustaining.

In getting out the shop drawings for this bridge only a small force of expert draftsmen was selected at first and the number was gradually increased. It required three years to complete the office work. It was thought best not to subdivide the work among different assistant engineers, but to give one man full charge from beginning to end. All drawings were prepared under his direction, and whenever a drawing was completed it was examined by him carefully in regard to lengths, sizes, strength of all details, notes for shops, inspectors and transportation. It was only then that these drawings were forwarded in duplicate to the Consulting Engineer for his approval. If approved, seven additional prints of complete, checked drawings were sent to the Consulting Engineer for his approval and six copies were returned by him to the Bridge Company, who sent five copies to the Chief Engineer of the Quebec Bridge Co. The Phoenix Bridge Co. received one print back approved by the Dominion Government. The drawings were made in such a manner that all information necessary for the proper execution of the work in the shop was given, as clearances, notes explaining any peculiar detail or calling attention to all important dimensions regarding width, depth, etc., and information for the sole use of inspectors.

In building some of the posts with many heavy top links, where a large number of plates form one link, these links were bound to vary in thickness. The collars for pin packing were only ordered after each post was built and the clearances reported to the office. The second checking of finished drawings in regard to spacing rivets, fitting to other members, etc., had at first been done by the assistant engineer in charge, but this work was then assigned to other assistant engineers, thus relieving the one in charge of this burdensome work and giving him more time for the preparation of drawings.

As the checking of drawings had to be done by different assistant engineers, some doubt arose as to whether some errors might not occur as a result, but thus far the part of the bridge erected has proven that the checking has been done in a most excellent manner.

At no time during the progress of the office work were more than 18 men working upon it at a time. If twice that number had been employed the result would have been the same. The rate of progress depended upon the rapidity with which the person in charge performed his work.

As said before, the preliminary details were made with all calculations and the best results were obtained in preparing the final details. Every draftsman who was employed in the preparation of the drawings for this bridge will testify to the unusual care which was taken to bring this work to a successful conclusion. In comparing the details of this bridge with those of existing long spans with pin connections, one finds, for instance, at the intersection of diagonals with hangers and secondary posts, a large number of forked members with long, thin jaws, packed on one pin, which certainly does not give the impression of good, rigid connection. We have striven, in preparing the details for this bridge, to avoid members with long, thin forks. Even a casual observer will notice the absence from this bridge, and it will also be evident to him that a degree of stiffness in the connections has been secured through the application of links not obtained in similar pin bridges before.

## Testimony of PETER L. SZLAPKA, Designing Engineer of the Phoenix Bridge Co.

[In Full.]

Mr. Szlapka has been engaged with the problem of the Quebec Bridge for fully ten years. His testimony indicates that he was working on it as early as 1897 and since that time the elaboration of the successive designs and the final plans has occupied a large part of his time. Insofar as the Quebec Bridge can be said to be the work of one man, Mr. Szlapka is that man. The soundness of the bridge had become so ingrained in his mind that, as he testifies, on Aug. 29, 1907, he was totally unprepared to see any symptom of failure in the bend of Chord A 9 L reported on that day. In the course of his examination, Mr. Szlapka filed a stress sheet for the conditions existing at the time of the collapse. As quoted by the examiner in a subsequent question, this shows a stress of 18,000 lbs. per sq. in. in Chords 9 of the anchor arm, the stress under which they failed. Both Mr. Deans and Mr. Szlapka, it will be noted, hold that Chord 9 of the right-hand (East) truss failed first, while Mr. Cooper believes that Chord 9 of the left-hand truss was the first to go.

Q. What is your official position in the Phoenix Bridge Co.?

A. My official position with the Phoenix Bridge Co. is that of Designing Engineer.

Q. How long have you occupied this position?

A. For the last 21 years.

Q. When did you enter the Phoenix Bridge Co.'s service, and in what capacity? How much time during this period have you spent in drawing office, in computing department, in the erection office, and in field work?

A. I entered the Phoenix Bridge Co.'s office in 1880 as bridge draftsman. I spent six years in the drawing room and twenty-one years in the designing department. I was not engaged either in the erection department or in field work.

Q. In your present capacity, are you the responsible Designing Engineer for the company?

A. Yes.

Q. Previous to entering the service of the Phoenix Bridge Co., will you please state, generally, what your experience in bridge work had been?

A. I took a seven years' classical course in a German college, and a four years' general engineering course in the Royal Polytechnic School, in Hanover, Germany, and when entering the service of the Phoenix Bridge Co. I had the above thorough theoretical college training.

Q. During the period you have occupied your present position, will you please state what large bridge structures you have designed which have been built by the Phoenix Bridge Co., giving dates and general dimensions?

A. The following are some of the largest structures designed by me, viz:

Ohio River Bridge, at Cincinnati, Ohio, consisting of two (2) 490-ft and one (1) 550-ft double-track through spans, designed in 1888; the three spans weighing over 5,000 tons.

Ohio River Bridge, at Louisville, Ky., consisting of three (3) 546-ft. single track through spans, built in 1890; the three spans weighing 2,700 tons.

Tennessee River Bridge, at Decatur, Ala., one (1) 382-ft. draw span, built in 1901, weighing 500 tons.

Tennessee River Bridge, at South Pittsburg, Tenn., built in 1906, weighing 650 tons, one (1) 436-ft. single-track through draw span.

Bridge over St. Lawrence River, at Cornwall, Ont., three (3) 365-ft. single-track through spans, built in 1897, weighing 1,500 tons.

Bridge over St. Lawrence River, at Cornwall, Ont., main span, 840-ft. cantilever, built in 1898, weighing 1,200 tons.

Q. Please state your office engineering organization in the course of designing, detailing and checking your bridge work?

A. The general design of the bridge was prepared in the Designing Department, under my personal supervision. The work was then handed to Mr. Scheidl, Engineer in charge of the shop drawings. The main features of the design were explained and complete

specifications, as prepared by the Consulting Engineer, were given to him for his guidance in designing the details of the bridge. After preparing the general preliminary details of the most important connections, Mr. Scheidl discussed same with me, and changes were made, if found necessary. These preliminary drawings were discussed with Mr. Cooper and changes made as directed by him. After these preliminary details were established to our complete satisfaction, an assistant engineer and a number of first-class draftsmen (varying from five to fifteen) were assigned to Mr. Scheidl's charge, who prepared the final shop drawings, using the preliminary plans for their guide. The final shop drawings were only then considered as complete, after being changed as many as seven or eight times, when they were entirely satisfactory to us and when we believed they could not be improved. The general calculations were checked twice in the Designing Department and twice in the drawing room during the preparation of shop drawings.

Q. Did you design the Quebec Bridge.

A. Speaking in a general way, yes. The bridge is of such a magnitude as to be beyond the ability and physical endurance of one man. The results achieved represent combined efforts on the part of all the departments of the Phoenix Bridge Co., under the direction of the Consulting Engineer, Theodore Cooper.

Q. Was the regular organization of your department made use of in connection with the designing, detailing and checking of the Quebec Bridge, or was there any special organization for this purpose? Please state your process in detail, fully explaining all precautions taken to reach accurate results?

A. The regular organization of my department and of the drawing room were entirely capable of dealing with the problem. No addition was found necessary. The shop drawings were first checked by Mr. Scheidl, the engineer in charge, as to strength, general clearances, facility of erection and connections with other members. The Assistant Engineer, under immediate charge of Mr. Scheidl, checked the drawings as to their correctness for all connections and for shop work. At certain stages of the work, when the drawings were too far ahead of the checking, as many as six engineers and five of the best draftsmen were used as additional help in checking. The few errors found during erection are the best evidence how carefully all the shop drawings were prepared and checked.

Q. We understand that your plan No. 1 of the Quebec Bridge, dated Nov. 30, 1897 (Exhibit No. 88), embodies information as to length of spans, cross-section of river and height of bridge. From whom did you receive this information?

A. The information referring to the length of spans, cross-section of river, and the clear height of bridge, was furnished by Mr. Hoare, Chief Engineer of the Quebec Bridge Co., on a plan which is in your possession.

Q. Please examine your plan No. 2, dated Dec. 7, 1897, and compare it with the plan dated Jan. 13, 1898, and signed by Messrs. Parent, Barthe and Hoare and say if these two plans are identical as to superstructure?

A. Our plan No. 2, dated Dec. 7, 1897 (Exhibit No. 89), is identical as regards the superstructure, with the plan dated Jan. 13, 1898, signed by Messrs. Parent, Barthe and Hoare.

Q. Is the plan of Jan. 13, 1898, practically a copy of your plan of Dec. 7, 1897?

A. Yes.

Q. Please file copy of plan No. 1 and plan No. 2, and also copy of the plan submitted with the tender to the Quebec Bridge Co. in 1899 for 1,600-ft span. (Filed.)

Q. Please file complete stress sheet and tables showing the unit stresses and net sections of all members, panel concentrations and estimated weight of structure divided between anchor arm, cantilever arm and suspended span corresponding with the design accompanying your tender? (Filed.)

Q. Was this stress sheet worked out exactly in accordance with the specifications sent to your company by the Quebec Bridge Co.?

A. In designing the 1,600-ft. span, the Quebec Bridge Co.'s specifications were followed in every particular, except as regards wind pressure under 30° to the horizontal, which requirement was disregarded as unnecessarily severe.

Q. Did the weights ascertained from your strain sheet agree with your assumed weights, and, if not, will you please state in detail what process you use in arriving at your final stress sheet, which was the basis of your tender of 1899?

A. The plans submitted with the tender being only of an approximate character, no recalculations were made based on the approximate weight ascertained from the first calculations.

Q. Was there any doubt in your mind at this time as to the existence of data sufficient to enable engineers of your experience to design this bridge, especially in regard to large compression members?

A. No, I had no doubt on the subject, but, as stated in the preceding answer, the first design was only approximate and the minor details were not considered at the time, except a few of the most important general points, which were given a careful study.

Q. Was this the largest structure that you had ever attempted to design?

A. Yes.

Q. In the course of the designing of this bridge did you consult with engineers outside of the Phoenix Bridge Co., and, if so, with whom?

A. I did not consult with any outside engineers as to the design of the bridge, except with Mr. Theo. Cooper, Consulting Engineer.

Q. On April 22, 1900, you prepared two plans, one indicating the river span as 1,723 ft. and the other indicating it as 1,800 ft. Will you please say what caused you to make these plans?

A. About April, 1900, I received orders from Mr. John Sterling Deans, Chief Engineer of the Phoenix Bridge Co., to prepare a plan with a central span of 1,800 ft. Not understanding that the length must be exactly 1,800 ft., the panel lengths working out better for a slightly shorter span, I selected a central span of 1,723 ft., keeping the length between the anchorages 2,800 ft., as required. After I was informed that the central span must be exactly 1,800 ft., I prepared another plan in harmony with these instructions.

Q. Subsequently to April 22, 1900, you made several general plans of the Quebec Bridge, all of which show the river span at 1,800 ft. Was the change in span from 1,600 to 1,800 ft. entirely feasible from an engineering point of view?

A. Yes.

Q. When the 1,800-ft. span was decided upon, what recalculation of the structure did you make, and will you please file copies of your complete original stress sheets and tables for an 1,800-ft. bridge and anchor arm showing unit-stresses, net sections, load concentrations, and erection stresses; also, please attach to these strain sheets a bill of weights and the data showing dead, live, wind, and snow loads used in calculations. What were your reasons for adopting the lengths of spans?

A. During May and June, 1900, only the suspended span and the cantilever arms were recalculated for the new length of the central span, according to Quebec Bridge Co.'s specifications. No table of weights was prepared at this time. As regards the lengths of the cantilever arms and the suspended span, the latter was made ⅝ of the main central span; the usual length of the suspended span varies from ⅝ to ½ of the central span. I selected the lower limit in order to reduce the erection stresses at the connection of the suspended span with the cantilever arm. I also believe that this arrangement enhances the beauty of the design. The anchor arm was made 500 ft. by order of the Chief Engineer of the Quebec Bridge Co., which length appeared to be desirable in order to avoid reversed stresses in the top and bottom chords, according to the different positions of the live load.

Q. Up to this time had there been any work done in the way of the designing of details, or were the details merely roughly estimated?

A. The details were merely roughly estimated.

Q. Was the study of the design what you would call complete, having regard to its unprecedented dimensions and also having regard to the fact that details had not been fully considered?

A. A continuous study was given to the general design, while the details were perfected as the work progressed. The final design, I believe, cannot be improved upon.

Q. When did you begin the study of details for this structure?

A. Many of the details were roughly sketched out as early as 1897 and 1898.

Q. What progress had you made in the study of details between January, 1902, and June, 1903, and did you find in the course of this study that the weight of the details was very considerably overrunning your previous estimate of weights?

A. All important general details were drawn out by Mr. Scheidl, during 1902, as a basis for further study and perfection. The details at that time, not being final, their weights were not ascertained, in order to compare them with the rough weights of details assumed in the calculations.

Q. During this period Mr. Theodore Cooper was Consulting Engineer for the Quebec Bridge Co. Did you confer with Mr. Cooper during this period on questions of design, and, if so, will you please explain fully?

A. The outline of the bridge was discussed with Mr. Cooper fully. The lengths of the cantilever arm and the suspended span were approved by him, while the length of the anchor arm was specified by the Chief Engineer of the Quebec Bridge Co., governed by local conditions. The panel length, the arrangement of the web system and the depths of the trusses were discussed and approved. Mr. Cooper was at first of the opinion that trusses inclined from the vertical would be preferable, so that the effect of any settlement of the main piers would not be as readily perceived as in the case of vertical trusses, when one or both trusses might be out of vertical. This question was finally settled by Mr. Cooper in favor of vertical trusses in Oct., 1903. Another point raised by Mr. Cooper was the vertical end posts of the anchor arm. His attention was called to the fact that the vertical posts were preferable to inclined end posts, admitting of simpler details for end portals, and, at the same time, giving to the anchor arms the appearance of greater length than would be the case with the inclined end posts. This question was also settled by Mr. Cooper in favor of vertical end posts October, 1903.

Q. In the final designs for the structure, were you striving to design the best bridge possible, or were you limited in any way as to the ultimate cost of the structure, and, if so, to what extent?

A. In designing the structure, I followed closely Mr. Cooper's specifications, put forth every effort to obtain the best results, and to secure the best bridge possible, irrespective of ultimate cost.

Q. Had you specific instructions on this point, and, if so, from whom and what were they?

A. I have never received any instructions to sacrifice any features of good design in order to keep the structure within any specified cost.

Q. When business arrangements were made between the two companies, so as to justify you proceeding actively with the work in the Designing Office, what part of the structure did you commence your studies on?

A. The floor system was figured first (July 1, 1903), followed by calculations of the suspended span (November, 1903-February, 1904).

Q. Will you please file a copy of the strain sheet (giving the corresponding information asked for previously on the other strain sheets), which formed the basis of your detail design of the structure? (Filed.)

Q. Were the data available at this time in regard to the weights of the cantilever arm and the suspended span sufficiently accurate to enable you to correctly design the anchor arm in detail?

A. The weights of the cantilever arm and suspended span were then believed to be sufficiently accurate—and were so approved by Mr. Cooper—to enable me to correctly design the anchor arm. Subsequently, when the suspended span and cantilever arm were developed, it was found that the actual weights were somewhat in excess of those assumed for the calculation of the anchor arm.

Q. At this period we find that certain modifications in the specifications were suggested by Mr. Cooper. Were these modifications discussed between you and Mr. Cooper? What modifications in the Quebec Bridge Co.'s original specifications did you suggest to Mr. Cooper and what provisions of the written specifications were set aside by Mr. Cooper's orders?

A. On May 13, 1903, the Phoenix Bridge Co. received a letter from Mr. Cooper, stating that he was ready to see Mr. P. L. Szlapka to talk over specifications for the main bridge. I visited Mr. Cooper on May 14, and received from him a full explanation of the loading and unit stresses to be used in proportioning the members of the main bridge. Mr. Cooper impressed upon me the importance of strictly following his specifications, but, at the same time, to be prepared to consider special important features with him irrespective of the requirements of his written specifications. In view of Mr. Cooper's proposition to use, for certain combinations of conditions, unit stresses as high as 24,000 lbs., or ¾ of an average elastic limit of 32,000 lbs., I mentioned to Mr. Cooper the fact that a German professor (I do not recollect his name at present) proposed to use a fraction of the elastic limit for unit stresses for truss members after first allowing for irregularity of shop work, for imperfect erection, for flaws in material, etc. A table showing extreme velocities of wind at various stations, as reported by the United States Government, from 1883 to 1893, for his consideration in discussing the question of wind pressures, I presented to Mr. Cooper. I did not suggest any modifications in the Quebec Bridge Co.'s specifications. After learning from Mr. Cooper his exact wishes as to the loading and unit stresses, the calculations were begun on the floor system, followed by the 675-ft. suspended span.

Q. Please file a copy of all modifications of the Quebec Bridge Co.'s specifications which were approved by Mr. Cooper, and which were actually made use of and adhered to throughout the designing of the structure, as to loading, unit-stresses, quality of material, and workmanship. (Filed.)

Q. Did you fully concur in all the amendments made in the specifications, having in mind that you were endeavoring to produce the best possible bridge?

A. The amendments made in the specifications by Mr. Cooper were not subject to my approval.

Q. Will you please state the exact condition of the work of designing, what detail plans had been completed and approved by Mr. Cooper up to Oct. 1, 1904?

A. Stress sheet, suspended span, approved by Mr. Cooper, March, 1904. Stress sheet, anchor arm, approved by Mr. Cooper, June, 1904. General detail draw-

ing, suspended span, approved by Mr. Cooper, May, 1904. All typical drawings of top and bottom panel points were prepared and approved by Mr. Cooper, May, 1904. Plate floorbeams and stringers were approved, July, 1904. Shop drawings of two end panels were approved, August, 1904.

Q. At this date had you completed the stress sheet for the cantilever arm or for the suspended span, and had you designed the main traveler?

A. Stress sheet of suspended span completed February, 1904. Stress sheet of cantilever arm completed December, 1904. Main traveler designed April, 1904.

Q. Previous to October, 1904, we understand that you had completed the design of the anchor arm and that many of the detail plans had been approved by Mr. Cooper. What was the exact condition of the design of the cantilever arm at this date—October 1, 1904?

A. The stresses in the cantilever arm were figured with the exception of the erection stresses.

Q. What was your practice in regard to issuing orders to the shop to proceed with work? Did you, in each case, await the approval of Mr. Cooper before commencing the construction of any piece of work?

A. As soon as shop drawings were completed in the drawing room, and approved by Mr. Cooper, they were placed in the shops; and in some cases we did not await the approval of Mr. Cooper as has been correctly explained by Mr. Deans.

Q. Was any work of construction commenced or material ordered before Mr. Cooper's approval of the plan was obtained, and, if so, state what was done or material ordered and why this course was followed.

A. In order to insure continuation of the work in the shops and in the field, lists of materials and shop drawings were placed in the shops, in some cases, before the approval of the plans by Mr. Cooper, at the risk of the Phoenix Bridge Co., as has also been correctly explained by Mr. Deans.

Q. Was any work commenced in the shop, or material ordered before the plans had been approved by the Department of Railways and Canals, and, if so, please give details and say why this course was followed.

A. For the same reason, materials were ordered and shop work commenced, in some cases, before the approval of plans by the Department of Railways and Canals.

Q. Did you consider the approval of the plans by the Department of Railways and Canals a condition precedent to the fabrication of the bridge?

A. No.

Q. Please state when the fabrication of each of the lower chord sections of the anchor arm was commenced.

A. Chords finished in the shops as follows:

| | | |
|---|---|---|
| No. | 1. | Oct. 19-Oct 20, 1904. |
| | 2. | Oct. 24-Oct. 27, 1904. |
| | 3. | Nov. 3-Nov. 5, 1904. |
| | 4. | Nov. 12-Nov. 14, 1904. |
| | 5. | Nov. 25-Nov.26, 1904. |
| | 6. | Dec. 3-Dec. 6, 1904. |
| | 7. | Dec. 13-Dec. 17, 1904. |
| | 8. | Dec. 24-Dec. 31, 1904. |
| | 9. | Jan. 7-Jan. 16, 1905. |
| | 10. | Jan. 18-Jan. 19, 1905. |
| | 11. | June 3-June 10, 1905. |

Q. Did you consider that the unit stresses used in the designing of the anchor arm, as determined under the revised specifications adopted by Mr. Cooper, were up to the extreme limit of economy in design and safety to the structure?

A. Yes.

Q. In finally developing the stress sheet for the cantilever arm and the suspended span, did you find that the weights produced were in excess of those estimated in the design of the anchor arm?

A. Yes.

Q. Did these excess weights tend to increase the stresses in the anchor arm?

A. Yes.

Q. Was the detail design of anchor arm altered so as to meet these increased stresses?

A. No.

Q. Were the unit stresses in members of the anchor arm increased beyond the requirements of the specifications above referred to?

A. The weights of the suspended span, and of the cantilever arm, assumed in the first calculation of the stresses of the anchor arm, were smaller than the weights as finally obtained. Consequently, the stresses of the anchor arm, due to these increased weights, were increased, the anchor arm having been built in the meantime.

Q. Please file a stress sheet of the anchor arm, indicating in detail any such changes in unit stresses. (Filed.)

Q. Did you consider that these increases in unit stresses were still within the limits of safety?

A. Yes.

Q. Why was not the whole scheme of the bridge fully considered in detail before shop work commenced?

A. This was not practically possible. General experience enabled us to proceed without occupying valuable time and the time limit precluded any such arrangement. This followed the usual course of business in such cases.

Q. Having in view the unprecedented dimensions of this structure, was it the proper course to pursue, or did you pursue the ordinary course, as followed previously in connection with bridge building?

A. The ordinary rule, which is imperative in all cases, irrespective of the unprecedented dimensions of this structure, was followed.

Q. Whose instructions did you follow in adopting the above course, and what were the instructions?

A. I received my instructions from Mr. Wm. H. Reeves, General Superintendent, and Mr. John Sterling Deans, Chief Engineer, of the Phoenix Bridge Co., viz.: to place with the shops any shop plans as soon as approved, and to generally arrange the office work so as to insure continuous working on the bridge, in the shops and in the field.

Q. Were your relations with Mr. Cooper of a perfectly cordial nature throughout the whole period of the designing and erecting of the Quebec bridge?

A. Yes.

Q. Did you freely consult him on all matters?

A. Yes.

Q. Was Mr. Cooper's criticism of plans and design such as you might expect from an engineer of his experience and ability?

A. Yes.

Q. Was Mr. Cooper aware of the exact conditions of design on Oct. 1, 1904, at which period he had approved the design of a large portion of the anchor arm, and was he aware that strain sheets for the cantilever arm had not been made?

A. Yes.

Q. Did he approve your assumptions of weights for the designing of the anchor arm, and, if so, we would like you to establish this fact?

A. Examining the stress sheets thoroughly and finally approving same in every particular, Mr. Cooper certainly, by this very fact, approved every main feature given on our plans; therefore, also, the assumed dead load.

Q. Did Mr. Cooper complain to you at any time of the growing weight of the structure and with what result?

A. No.

Q. Did he order recalculations to be made, or, to your knowledge, did he make them himself?

A. Mr. Cooper did not order any recalculations. Knowing, however, that the weights assumed for calculations were exceeded by the actual shipping weights as reported to him by his inspectors, he, no doubt, made some calculations, as he remarked to me on one occasion during 1906 that "this fact did not amount to anything."

Q. Did Mr. Cooper intimate to you at any time that there was a limit which the cost of this bridge should not exceed, or did he complain at any time on the grounds of increasing cost?

A. Never.

Q. What was Mr. Cooper's reason for complaining of the increasing weights?

A. Mr. Cooper never complained to me of the increasing weights.

Q. From your knowledge of Mr. Cooper, would you consider that he would associate himself with a work which was inferior in any respect without protecting upon points which he considered inferior or inefficient?

A. I would not suppose anything of this kind for a moment, recognizing in Mr. Cooper the highest type of an able and honest engineer.

Q. What changes in general design or detail did Mr. Cooper suggest, and did these changes enhance the value of the structure or detract from its value?

A. Mr. Cooper, amongst others, made the following suggestions:

1st. Arrange anchorage of wind bent on anchor piers so that anchor bolts resist wind shear only, while the upward pull is transmitted to the anchor pier by the anchor bars only—Adopted.

2d. Change friction (due to lateral wind pressure and change of temperature) between end floorbeam of anchor arm and top strut of wind bent from sliding to rolling friction—Adopted.

3d. Arrange expansion of floor system so that no undue bending is produced in the floorbeams—Adopted.

4th. Arrange expansion between suspended span and cantilever arm, at both ends, instead of at one end as proposed by the Phoenix Bridge Co.—Adopted, but not considered an improvement by me.

5th. Arrange packing of eyebars in top chord of anchor arms, as per Mr. Cooper's two sketches—Not adopted. Found entirely faulty by the Engineering Department. The Phoenix Bridge Co.'s packing adopted with very small modifications suggested by Mr. Cooper.

6th. Provide wooden traction arrangement between suspended span and cantilever arms, as shown on Mr. Cooper's sketch—Not adopted, as not being in harmony with the high standard of the rest of the details of the bridge. Its design is still open. Mr. Cooper urged the adoption of this wooden arrangement as it could easily be made by a track-walker and attended to by him in case of repairs. Not wishing to criticise Mr. Cooper's scheme myself, I remarked that it might be criticized by the profession; to this Mr. Cooper answered "there is nobody competent to criticize us."

7th. Change lateral bracing in floor system, as per Mr. Cooper's letter—Not adopted, as inferior to the Phoenix Bridge Co.'s design.

Q. Were you in any way hurried or rushed in the preparation of the design or did you consider at all times that you had ample time and opportunity for making all necessary studies in order to make the design perfect?

A. We were pressed in our office work, but never sacrificed the perfection of the plans to the requirements of the shops or the field. I did consider that we had ample time and opportunity for making all necessary studies.

Q. From your knowledge can you say that Mr. Cooper critically examined all the plans submitted by him? We would like to know from you your candid opinion on this point and if you felt that when you received a plan from Mr. Cooper approved by him it had been scrutinized and analyzed as fully as possible?

A. From my personal observations, I believe that all plans were carefully examined in Mr. Cooper's office; either by Mr. Cooper personally, or by his able assistant; the latter reporting on all important questions to Mr. Cooper. The fact that even unimportant misfitched connections did not escape the attention of Mr. Cooper's office certainly proves the thoroughness and careful study bestowed on the examination of the plans.

Q. Had you full confidence in Mr. Cooper as Consulting Engineer and did you feel that in case of doubt arising in your own mind consultation with Mr. Cooper would assist you materially in arriving at definite conclusions on points upon which you might have certain doubts?

A. Yes.

Q. Did you, during the design and construction of the bridge, consult Mr. Cooper on matters such as are referred to in the previous question and were these consultations of material benefit to you in the designing of the structure? If you can give details, please do so.

A. Considering Mr. Cooper one of the ablest and most experienced bridge engineers in the country, I discussed fully with him all main features of the bridge. His advice and directions were always sought and appreciated.

Q. Was the design of the compression members particularly discussed by you with Mr. Cooper, more especially with reference to the lower chords, and, if so, will you please state precisely what special points were discussed in connection with these members and what were the circumstances that led to the discussion on the details of these members in particular?

A. After the first sections of the lower chords of the anchor arms were constructed in the shops, Mr. Reeves, President of the Phoenix Bridge Co., remarked, in our engineering office, that the lattices on the chords appeared too light and that they were liable to be injured or damaged in handling in the shops and transportation to site. I answered that lattices of any size might be injured and destroyed if carelessly handled in the shop or in transportation. This conversation was reported by me to Mr. Cooper. He answered that he looked into the question of the strength of the lattices while checking the plans and that "we had it all right."

Q. Were you unable to consult with Mr. Cooper at any time owing to the condition of Mr. Cooper's health?

A. No.

Q. How often did you go to New York to consult with Mr. Cooper? How often did Mr. Cooper come to Phoenixville?

A. I visited Mr. Cooper about once a month. Mr. Cooper visited Phoenixville twice during the entire process of designing and constructing the bridge.

Q. Was Mr. Cooper aware that it was the intention to use the big traveler for erection purposes as far as the center of the suspended span and, if so, in what manner was he made aware of this, and was he aware that all of the spans were figured with the big traveler in the center of the suspended span?

A. Mr. Cooper was aware that it was the intention to use the large traveler for erection purposes as far as the center of the suspended span, from conversations with me, and owing to the fact that he approved the unit-stresses due to the erection based on the above condition.

Q. Will you please file a strain sheet using as your data for dead-load stress the actual shipping weights of material constructed, together with the concentrated panel loads and the other information called for as in the case of the other stress sheets? Indicate the net sections of each member on this stress sheet in red as constructed and in black as demanded by the stresses under the specification to which you were working, and state generally what the comparison between the results is? (Filed.)

Q. What was the first intimation you had that would lead you to suppose that any member in the bridge was showing distress?

A. When my attention was called to the curved condition of chord 9-L, south anchor arm, by Mr. Birks' report, enclosing a sketch of the chord, on Aug. 29.

Q. For what reason were the repairs on the splices at 7 L and 8 L, cantilever arm, not promptly considered and executed?

A. Repairs were promptly considered and submitted to Mr. Cooper for his approval. His decision was awaited when the bridge fell.

Q. Did you, throughout the construction of the work in the shops, keep generally in touch with what was being done? Did you make a special examination of important members before they left the shop? Can you say that chords 9 L, anchor arm, and 9 R and 8 R cantilever arm, were in perfect condition when they left Phoenixville? If they were in perfect condition when they left the shops to what do you attribute the later deformation of these members?

A. I kept generally in touch with the construction of the work. I examined carefully many important members before they left the shop. I am not able, however, to state in what condition chord 9 L, south anchor arm, or 9 R and 8 R, cantilever arm, left the shops. I do not know to what to attribute the deformation of the members.

Q. Will you please file a stress sheet and indicate upon it all unit-stresses as existing in the bridge immediately preceding the accident of Aug. 29? (Filed.)

Q. Assuming the bridge to have been successfully completed what would have been the unit-stress in chord 9, anchor arm?

A. 21,200 lbs. working stress, including live and dead-load and snow.

Q. In your judgment what was the weakest part of the structure, first, during erection, and, second, when completely erected?

A. The compression members of the bridge.

Q. Where, in your judgment, did the initial failure take place? Please give your opinion as to the sequence of the fall of the structure?

A. It appears reasonable to suppose that after the fall the center of gravity of the top mass of the metal should be on that side of the center line of the bridge on which the initial failure of any important truss member took place. This condition of the top chords actually existing clearly indicates to my mind that east chord section 9, south anchor arm, failed first, dragging the west chord, section 9, after it. The two main shoes have been pushed off their pedestals towards the south anchor pier by an unbalanced horizontal force over the main pier. This condition was created by the destruction of chord 9, anchor arm, and the release of the horizontal component of chord 10, cantilever arm.

Q. What reason do you assign for chord 9 in the anchor arm yielding under a unit-stress of 18,000 lbs. when they were calculated to safely carry a much higher unit-stress?

A. The main sections being sufficient to resist the stresses existing on that day, either the detail parts uniting the four ribs failed, or the ribs buckled individually, or both.

Q. In designing the compression members did you exhaust every known source of information and were they designed after the full consideration of all known or available data on the subject?

A. Yes. There were no precedents for designing compression members of this magnitude. Tests made on small pieces do not furnish adequate information for members of many times their size.

Q. What was the largest compression member you had heretofore designed and what unit-stresses were used in it?

A. The largest compression member designed by me had 240 sq. ins. and the unit-stress was 14,000 lbs.

Q. Did the use of these high unit-stresses demand mechanical work in the fabrication of the structure superior to that demanded by work designed for lower stresses?

A. Yes.

Q. In this connection what would you consider the limit of good practice in the variation in lengths of the ribs comprising a lower chord section?

A. One sixty-fourth of an inch (1/64 in.)

Q. Was this variation exceeded in any cases in the construction of the lower chords?

A. Not to my knowledge.

Q. Did the quality of the shop work meet with your entire approval?

A. Yes.

Q. In the light of recent events have you changed your opinion as to the value of data available for the successful design of large compression members? If so, will you explain in detail?

A. There is no reliable theory established, nor are there any results of extensive tests on compression members on record as regards detailing of these large members. No data exist showing clearly when lattices only are sufficient to unite fully two or more ribs into one rigid unit. There is, no doubt, a limit to the depths of compression members when lattices only may be used, and when, on the center line of the ribs, in addition to the lattices, a continuous horizontal plate-girder must be added. We have no data showing how much more efficient top and bottom cover plates are than heavy lattices, nor do we know when, in addition to top and bottom cover plates on the center line of the ribs, girders as above mentioned should be used. All doubt as regards these important features of detailing large compression members should be eliminated by extensive tests, as arguments advanced by theoretical investigations are based on more or less vague assumptions.

It is the duty of the entire engineering profession to strive to secure numerous tests to establish rules to be followed in designing compression members of large size, in order to replace or to corroborate present opinions.

Q. Similarly have you changed your opinion with regard to the use of high unit-stresses, either in tension or compression? If so, will you give your reasons fully?

A. No; high unit-stresses may be used in designing, if members in tension or compression are proportioned by rules supported by actual tests. But under existing conditions, I would not advocate such extreme unit-stresses.

Q. In splicing large compression members do you consider that the area of the splice-plates would be sufficient if they represented from 15% to 20% of the area of the member?

A. Yes.

Q. Would you consider that a splice which was to be 60% bolted up was properly bolted if 30% drift-pins were used?

A. Yes.

Q. Did the action of the anchor arm during erection meet your expectations as previously calculated, or did it act in an unexpected manner? Please file a statement or diagram showing the movements of the camber blocking, giving the dates of orders issued in respect to these movements, and when each panel point was released?

A. The anchor arm, during erection, acted generally as expected. Considering the height of the falsework (160 ft.), the wooden falsework foundations resting on natural ground, the variations in the field as compared with the office calculations were insignificant. Exhibits attached.

Q. Were there any matters in the process of erection which were brought to your attention which indicated in any way miscalculation? If so, please describe them?

A. None, whatever.

Q. Please state as concisely as possible the history of the development of the eyebar system in the bridge, stating what tests were made, and at whose instance; and also giving the general results obtained. And will you please file copies of the blue-prints of the eyebar heads that were tested? Were other tests on full-size members made, and if so give details?

A. When making the first design for the bridge, in 1897 and 1898, I found that large eyebars must be used. In order to decrease their number and to thus reduce the chances of errors in boring, to a minimum, and also to obtain shorter pins, 15-in. and 16-in. wide eyebars were considered, not over 2 ins. thick, thicker bars being less reliable in testing. This latter feature was especially important, and well known to me since I knew the unreliable and often unsatisfactory results of tests made in our large testing machine for all bridge companies in the United States, on bars over 2 ins. thick. I was requested many times by the officials of the company to be sure, when determining sizes of eyebars, to keep the thickness, as much as possible, below 2 ins. unless it were necessary, in exceptional cases, in order to overcome difficulties encountered in arranging eyebars and pins.

For our information we made preparations to test 15-in. × 2-in. eyebars as early as 1900—ten of these bars 15 × 2 ins., about 15 ft. long, were manufactured and tested, with very satisfactory results, in 1901—demonstrating that bars of this size may be successfully forged, and that reliable results may be obtained.

Seventy-three full-size tests were made on 10-in. and 15-in. eyebars between July, 1904, and April, 1907, as required by the specifications, and ordered by Mr. Cooper.

In order to ascertain the character of stresses and resulting strains in the metal of the eyes, the latter were divided by lines parallel with the longitudinal axis of the bars, and by lines at right angles thereto into squares with 2-in. sides. These lines, in their new positions after the tests, were closely examined, and information secured, useful in designing the size and shape of the eyes. No other full-sized tests were made.

Q. Did you visit the bridge site during erection and will you please give the dates of these visits? Please file copy of your personal diary covering the Quebec Bridge work?

A. I visited the bridge in May, 1901; June, 1905; June, 1906, and August, 1907. Copy of my personal diary attached.

Q. Did you make a personal examination of chords 7 L and 8 L cantilever arm, in the structure? Did you personally examine any chords after erection, and on what dates and with what results?

A. No.

Q. What stresses did you classify as secondary stresses, and what secondary stresses did you make allowance for in your design, and in what manner did you make this allowance?

A. Secondary stresses due to the enforced position of the members in the structure were considered; but no allowance was made for them.

1st—In floor beams due to bending induced by railroad stringers during change of panel lengths of trusses. No allowance made as directed by Mr. Cooper.

2d.—In eyebars due to bending induced by deviation of the bars from longitudinal axis of bridge. No allowance made as directed by Mr. Cooper.

3d.—In end vertical posts of suspended span, due to temperature change. Insignificant.

Q. Mr. Cooper has stated that it is his opinion that the bridge could have been saved by promptly using timber blocking in the chords and strutting and bolts between the chords. What is your opinion?

A. I do not believe that the bridge could have been saved in any such manner.

Q. In the bridge as constructed, were any combinations of wind and loading considered which produced unit-stresses in excess of those permitted by the specifications under which you were working and to which you were limited? Give particulars as to each member so affected?

A. Combinations of wind and loading, assuming load increased by 50%, produce unit-stresses in

| | | | |
|---|---|---|---|
| Cantilever Arm | chd | 7 | 25,600 |
| | | 8 | 25,900 |
| | | 9 | 26,800 |
| | | 10 | 26,400 |

Q. Were these unit-stresses approved by Mr. Cooper?

A. Yes.

Q. Do you consider that this procedure affected the efficiency of the structure, and in what manner and to what extent?

A. The combination of conditions of loading being improbable, practically impossible, I do not believe that the efficiency of the bridge was affected by the high unit-stresses given above.

Q. Please file sketches of both travelers and indicate their loads—weights and maximum concentrations of load. (Filed.)

Q. When was it decided to use the small traveler, and for what reason was the system of erection changed? Who suggested this change, and did you approve of it?

A. In order to begin the erection of the north anchor arm early in the spring of 1908, the large traveler had to be removed from the south side, and re-erected on the north side in the fall of 1907, before it was possible to finish the erection of the entire south half of the central span. Therefore, another traveler had to be provided for the erection of the south half of the suspended span, only about one-quarter as large as the large traveler, thus effecting a considerable saving of metal in the suspended span.

The use of this small traveler was first suggested, and finally decided upon, by the Phoenix Bridge Co., about January of 1906, with my full approval. The original scheme of erection contemplated the use of the large traveler to the center of the suspended span; the erection stresses in the cantilever arms were so figured and sizes provided. The stress sheet of the cantilever arm was approved by Mr. Cooper, showing sizes for erection stresses for the above condition.

Q. Please file a stress sheet showing erection stresses only—on the assumption of the big traveler being used to center of suspended span. Did the change in the travelers as adopted reduce these stresses, and to what extent?

A. Erection stresses due to large traveler attached. Stresses in the suspended span, due to small traveler, were only about 25% to 33% of the stresses due to the large traveler.

Q. What calculations were made by you on Aug. 29, in respect to 9 L, anchor arm? If you arrived at a conclusion, please state what it was.

A. Knowing that every part of the bridge was figured with the utmost care as to its strength, that the results of the calculations were checked and compared at least three times in the Phoenix Bridge Co.'s office, that they were then sent to the Consulting Engineer for comparison with his calculations and for his approval, and that they were fully approved by him; knowing further that the shop plans were prepared under my personal supervision by a corps of able engineers and draftsmen, that these plans were redrawn several times; that they were then sent to the Consulting Engineer for his study and approval, and that they were all approved by him; knowing further that every part of the bridge was constructed strictly in accordance with these plans; knowing also that the erection was conducted carefully and strictly acording to plans prepared by the engineering department—knowing all these facts, I was forced to believe that on Aug. 29, 1907, the bridge was in a safe condition, and that no part could show the least sign of weakness due to stress, especially as the loads of the bridge on that day were such as to produce stresses in the truss members only about three-fourths of the

stresses the bridge was figured to be able to bear, with entire safety, after its final completion.

It was impossible for me to believe that the bridge was failing or that the amount of curvature in chord 9 L was as reported. Our Resident Engineer, Mr. Birks, stating on Aug. 29, on the telephone, that there was no distortion in any lattice, that all rivets were tight, that there was no change taking place in any part of the chord, I was further strengthened in my belief that there was nothing wrong with that member. I made rough calculations of the chord, however, using 14,000,000 lbs. axial stress, and an average curvature for the four ribs of the chord of 1½ ins., and found that even with this improbable curvature, the chord was not in a dangerous condition.

Q. Does the elastic limit given by usual specimen test bear a direct relation to full-size tests of plates, and what is it? Have sufficient tests been made to fully establish this?

A. Tests made on specimens of eyebar material show an elastic limit generally 10% to 15% larger than full-size eyebar. I am not familiar with any full-size tests made on wide plates in order to compare results with the specimen tests.

Q. Do you consider that the elastic limit or the yield point of a built-up member, such, for example, as two or more plates riveted together, and which are intended to act in unison, has ever been accurately ascertained, it being assumed that buckling does not occur? What relation do these results bear to similar tests of a member of the same proportions, but consisting of one thickness, providing the same area of cross-section?

A. I am not aware that tests of this character ever have been made.

Q. Do you consider that a large bridge member under eccentric stress may in time be so altered in form without failure that the irregularity of stress in the metal under the eccentric loading will disappear in whole or in part?

A. Yes.

Q. Please file a list of all groups of calculations that you made in connection with the bridge in chronological order, and state which stress sheets were used in designing the details of each part of the bridge. (Filed.)

Q. File copies of top chord packing which Mr. Cooper refers to in his evidence as having been sent to you by him. (Filed.)

Q. Please calculate and file a stress sheet showing the stresses in the main truss members of the anchor arm arising from a uniform loading of 6,000 lbs. per lin. ft. (3,000 lbs. per lin. ft. on each track) on anchor arm only. (Filed.)

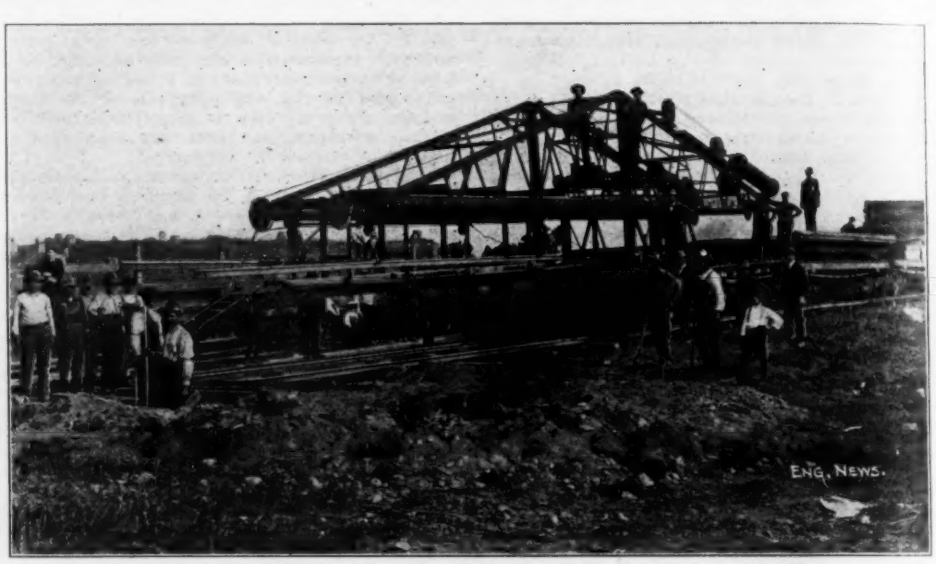
## A TRACKLAYING MACHINE WITH RAIL CARRIERS.

In the ordinary style of tracklaying machine, the rails and ties are delivered at the head of the front car and are then taken and put in place by gangs of men. In some recent modifications of these machines the rails are run out ahead of the front car by trolley carriers, thus reducing the amount of manual labor and expediting the work. The accompanying cut represents a new design of tracklaying machine specially designed for setting the rails in place upon the ties, so as to eliminate the large gang of men required to handle heavy rails. The ties, also, are delivered beyond the car.

The machine consists essentially of a flat car having a steel bent at each end to support a pair of riveted steel trusses, the forward ends of which project as cantilevers about 20 ft. beyond the end of the car. On the bottom chord of each truss run two hoisting trolleys having cables attached to rail tongs. On each truss are two air-cylinders with cables led to the trolleys; one serves to run them forward and the other to pull them back. In the middle of the car and projecting about 15 ft. in front of it is a trough fitted with a conveyor for delivering the ties at the head of the machine. Behind the tracklayer car are cars with rails sufficient to about 1,000 ft. of track, and having in the middle a conveyor (above the floor) which extends along the tracklayer car. Behind this again are the cars with ties, which are fitted with a conveyor extending under the rail conveyor and beyond it in front of the machine. Behind the tie cars and next to the locomotive is a car carrying miscellaneous supplies and having a steam engine which operates the conveyors. The movements of the trolleys and conveyors are controlled by a man stationed on the bridge carried by the tracklayer car.

Two rails are run out and lowered into position upon the ties. They are then bolted at the heel joints and temporarily connected with bridle bars to hold them to gage. The train then moves ahead, and as soon as it comes to a stop the conveyor is started, delivering the ties already in the trough. While the train is moving ahead and the ties are being distributed, the trolleys are run back and their rail tongs are attached to another pair of rails on the conveyor at the middle of the car. These are then swung to the sides and run out ahead of the machine, ready to be lowered in place as soon as the ties are laid. The spiking gang follows the tracklaying train, and spikes the rails while the ties are being distributed.

This machine was used by the Dibble-Hawthorne Co., contractors for the tracklaying on the electric interurban line of the Pacific Traction Co., starting from Tacoma, Wash. The rails were 33 ft. long, and from 2 to 2½ miles per day could be laid with the following force: 1 foreman, 4 men to operate the machine and feed ties and rails, 6 men to distribute and space ties, 4 strappers, 8 spikers, 4 nippers and 1 spike peddler. The machine was designed by Mr. C. O. Wescott, and is owned by the Wescott Tracklayer & Mfg. Co., of Puyallup, Wash. The use of tracklaying machines has been adopted in several cases on electric interurban lines, but is not practicable where 60-ft. rails are used, as is the case on several lines.




THE WESTCOTT TRACKLAYING MACHINE ON THE INTERURBAN LINE OF THE PACIFIC TRACTION CO.

## EXPERIMENTS AND COST ESTIMATES ON TREATING PORTIONS OF THE SEWAGE OF BOSTON, MASS.

In addition to the general experimental work on sewage treatment made during the last few years at the Sanitary Research Laboratory and Sewage Experiment Station, Massachusetts Institute of Technology, some studies have been made with a view of determining the practical possibilities of treating some or all of the sewage of Boston. A paper on this subject was submitted to the Sanitary Section of the Boston Society of Civil Engineers on Nov. 15, 1907, by Professors C.-E. A. Winslow and E. B. Phelps, of the experiment station named. This paper, it may be added, was based on a longer and more detailed one which will shortly be published in the "Technology Quarterly."

Experiments were conducted with the idea of determining the "feasibility of treating Boston sewage on trickling beds so as to secure organic stability." There was had in mind the fact that of the three sewage outlets into Boston Harbor, the one discharging at Moon Island was most likely to give rise to a nuisance demanding early abatement. The daily discharge of sewage at this point is now about 100,000,000 gals. With trickling or percolating filters of stone, 8 ft. in depth, about 50 acres of beds would be required to treat the sewage at this point at a 2,000,000-gal. per acre per day rate, as compared with about 133 acres of contact beds or 1,000 acres of sand filters. Experiments indicated that such filters would give a non-putrefactive effluent the year round, and that there would be no difficulty in operating the beds.

It was found that, as a preliminary treatment, good results could be obtained by treating Boston sewage for seven hours in septic tanks. By this means, about 40% of the total suspended solids and 60% of the fixed suspended solids would be removed from the sewage, and the effluent would show a decrease of about 25% in organic nitrogen and a corresponding increase in free ammonia. About 80% of the organic solids deposited in the septic tanks would be converted into gas. The study as a whole, however, indicated that septic tanks would not be necessary or desirable in this case. It was also concluded that it would be unnecessary to provide after sedimentation for the percolating-filter effluent, since "the currents of the harbor would be amply competent to care for the solid matter discharged if that matter were of an inoffensive and non-putrescible nature."

The possibilities of disinfecting the effluent from percolating filters were studied, and as a result it was concluded that it would be desirable to do this, making use of chlorin for that purpose.

As a site for works to purify the sewage now discharged at Moon Island, Thompson's Island was selected as most suitable. Estimates indicated that necessary connections could be made with this island and treatment works constructed for a total cost of about $1,800,000. These works would include 50 acres of 8-ft. percolating filters, equipped with gravity distributors; a grit chamber, and all necessary land, grading, etc. A 25-year 5% loan to pay for such works would call for a yearly capital charge of $126,800. The cost of operation, including extra pumping and supervision, would be about $70,000 a year, bringing the total cost up to about $200,000 a year, or $5.50 per 1,000,000 gals. Disinfection with chloride of lime would cost about $1.50 per 1,000,000 gals. additional, or $55,000 annually. The treatment of crude sewage with chloride of lime, it was estimated, could be effected at $3 per 1,000,000 gals., or $110,000 annually.

Experiments are now being made to determine the practicability of higher rates of filtration and shallower beds than those used as a basis for the estimates just given, and also to determine the cost of producing the chlorin electrolytically. The authors of the paper state that, in their opinion, the combination of trickling filters and chemical disinfection will solve the Boston sewage problem satisfactorily; and in the light of present knowledge these two methods are the most efficient and economical available for the purpose.

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On account of the unusual demands on our space for the report of the Isthmian Canal Commission and the testimony at Phoenixville before the Quebec Bridge Investigating Commission, it has been found necessary to defer the conclusion of the report of the Transvaal Commission on Winding Ropes and Safety Devices to our next issue.

The National Municipal League, at its convention at Providence, R. I., last week, added to its important constructive work previously undertaken, by appointing a committee on the relations between municipal, State and national health work. This, and also the adoption of a resolution to the effect that health-protective work ought to be entrusted to none but experts, was a natural outcome of a long session, held jointly with the American Civic Association, at which more than a half dozen papers on municipal health and sanitation were read. The papers, prepared by various health officials quite independently of each other, were remarkably harmonious in their expositions of how health board work is and should be carried on in representative American cities. The speakers agreed that health-protective work should be directed primarily to preventing the spread of communicable diseases from their sources, or from the hosts that harbor and throw off the specific germs that cause disease. A number of the authors urged in strong terms, and with forcible illustrations, the great need for the immediate establishment of a national department of health. Several of the authors referred to the expenditures by the U. S. Department of Agriculture of millions of dollars to gain and spread information regarding soil conditions and the diseases of plants and animals, and plead that equal consideration be given to efforts to prevent communicable diseases among men, women and children. If the National Municipal League enters upon a health-work campaign with such zeal and intelligence as it devoted to the framing of a model city charter, and to the formulation of a comprehensive system of municipal accounting, much good to the whole country may be expected to follow from the new, as there did from the old efforts. The League, it appears to us, might direct its attention most profitably to arousing many of the smaller communities, say those of under 100,000 population, to reform their health work and infuse into it more intelligently directed life. And it also might well investigate the exact needs for a national department of health and the best plan for such a department.

We give large space in this issue to the publication of extracts from the annual report of the Panama Canal Commission, just issued. While we have necessarily presented the report as a whole in much condensed form, we have given one section, that relating to "Contract vs. Hired Labor," in full. In this section the Commission explains in detail the reasons for the decision that the Government shall do the bulk of the work at Panama direct instead of by contract.

We commend this discussion to any of our readers who may still be unconvinced that the Government made a wise move in adopting the day's work plan.

The conditions at Panama are so peculiar that anyone who has given the matter any careful study realizes that any ordinary plan of contract work would be wholly out of the question there. The alternative was for the Government either to carry out the enterprise by direct employment of labor or else to let some percentage contract. It was the latter which Mr. Stevens proposed when he was in charge of the work a year ago; and if a contract were to be let at all, it is difficult to see how a fairer plan could be devised than that which was planned by Mr. Stevens.

Nevertheless, when this plan was put to the test of actual bidding, the results were found to be disappointing; and it was easy to foresee that if a contract were actually made under the plan proposed, there was a strong probability of friction and difficulties in the execution of the work, resulting very likely in litigation and delay. The contract itself was likely to be made a political issue; and the final decision reached, therefore, was to reject all bids and continue the work by the direct employment of labor.

This decision was arrived at prior to the organization of the present commission; but the statements in the present report, we take it, may be taken to be the views of those now in charge. These men have had large experience in the execution of important engineering works, both by contract and by day labor. What they have to say regarding the relative merits of the two plans and the conditions under which the one or the other will be found best is well worth placing on record.

There is good reason why the Commission should cover this subject fully. Influential interests are likely to be heard from on the floor of Congress, year after year, criticizing the Administration for not doing the work by contract. Many men will believe such criticism to be well founded. There was need, therefore, for a full and convincing statement on this matter, such as the Commission has furnished.

It is common enough nowadays to hear people remark that the Government is certainly going to build the canal; and that the work is going ahead rapidly and well; but that the cost will be "out of sight," "because Government work is always so costly, you know!"

While it is too soon yet to say what unit prices will be reached for the bulk of the work, when the whole plant is in place and the operating force is "tuned up," the figures for cost of excavation in the Culebra cut for the past year are certainly interesting. It appears that the average cost of excavating about 5,500,000 cu. yds., three-fifths of it rock, hauling it some ten miles by train, and distributing it on the dumps, was 82½ cts. per cu. yd., which figure includes an arbitrary allowance of 12 cts. per cu. yd. for the cost of the plant used. Remembering the tropical conditions, the heavy rainfall, the 8-hour day, the high cost of labor, fuel, materials and everything else, this indicates that they are not only "making the dirt fly" at Panama, but making a dollar do the most work possible—which has been set down by high authority as a proper function of the engineer.

Again, in dredging work, we learn that at La Boca, on the Pacific end, an old French ladder dredge excavated during the past year 1,213,000 cu. yds. at an average cost per cu. yd. of about 10½ cts., the material being towed out to sea in hopper barges.

Certainly figures like these deserve consideration by those who make rash generalizations as to the extravagance of Government work.

## THE PHOENIX BRIDGE COMPANY ENGINEERS' TESTIMONY ON THE QUEBEC BRIDGE.

We give up large space in this issue to the testimony of the Phoenix Bridge Company's engineers before the Canadian Government Commission which has been investigating the Quebec Bridge disaster. This testimony is not only of interest to those who are closely following this investigation to determine where responsibility for the disaster should be placed. It is a valuable exposition of the organization and methods of one of the largest and most noted of American bridge works. It contains a discussion of many of the complicated problems in design and erection which had to be solved in connection with the construction of the longest bridge span ever attempted. It gives the opinions of those most closely connected with the work as to the causes contributing to the wreck and the steps which should be taken to prevent similar disasters in the future.

We have set forth in our issues immediately following the disaster the chief deficiencies in design which brought it to pass. The testimony of the Phoenix Co.'s engineers confirms our statements.

As to where the responsibility lies for these defects, no doubt can exist that the primary responsibility lies with the engineering organization of the Phoenix Bridge Co., which made the designs and backed them with the weight of its experience and reputation. No doubt can exist, either, that a secondary responsibility rests upon the Consulting Engineer to whom all designs and plans were submitted for approval.

Either party may say with entire truth and propriety, as they do say, that they relied to a large extent on the other. Mr. Cooper was justified in relying on the Phoenix Bridge Co. organization to a large degree and on the other hand the Phoenix Bridge Co. officials were justified in feeling additional confidence because their designs were subject to the inspection and approval of Theodore Cooper. But the fact of such mutual reliance does not absolve either party from bearing his own burden of responsibility.

We are aware that this division of responsibility is sometimes criticized; but we do not believe such criticism is well founded. It is true that in this case the bridge fell; but no one who has followed the history of the structure can doubt that the chances of defective design would have been equally great had the Phoenix Co. worked entirely without the check of a consulting engineer or had the consulting engineer made the entire designs and details for the structure.

The normal and proper way of constructing any great engineering work which is done by contract is for two engineering organizations to work together. The one representing the contractor and the other representing the purchaser can check each other's errors, can study the work from different points of view and can produce a better and more economical result working in cooperation than either could working alone.

There is, however, a word of criticism which should be said respecting the position which Mr. Cooper nominally held and the responsibility actually laid upon him. Nominally Mr. Cooper was Consulting Engineer of the Quebec Bridge; and his salary was proportioned to a Consulting Engineer's duties. Actually he was called on to do the work which a Chief Engineer, with a competent corps of assistants, should perform. The title of Chief Engineer was borne by a man who appears to have carried no real responsibility in connection with the work.

Mr. Cooper received a salary which was originally a fair one for the service of a Consulting Engineer *doing consulting work only* on so large an

enterprise. It was cut in two, as related in his testimony; and this left him with barely enough to pay for an assistant on the office work and absolutely nothing for his own work and responsibility. Under these circumstances it is not surprising that he did not give the great structure any such frequent and thorough supervision in the office, the shop and the field as might have been given by an alert and competent Chief Engineer.

This fact is to be borne in mind in studying the history of the ill-fated compression members. Our readers who have followed our discussion of these members will recall that their defects are now well known to have been insufficient lacing and insufficient stiffening in the flanges of the separate ribs. These defects were undreamed of by the designers working over the drawing board. They simply followed the precedent set by other huge cantilever structures such as Morison's Memphis bridge and Modjeski's Thebes bridge and designed a massive four-web member on similar lines to those used in previous much smaller structures.

When this member came to be assembled in the shops, we are informed that some of the shop foremen became impressed with its lack of stiffness and rigidity, and eventually Mr. Reeves, the President of the company, suggested this to Mr. Szlapka, the Phoenix Company's designing engineer. The matter was discussed by Mr. Szlapka and Mr. Cooper but was dismissed as not important enough for serious investigation.

Surely there is a lesson here for engineers as to the value of supplementing office work with practical contact with work in the shop and field, as well as to the value of the aid that the workman of long experience can often render to the technically trained engineer. It was the workmen who were actually assembling and handling these huge chord members who became suspicious of them.

The actual masses of metal when lifted and moved in the shop processes revealed things that were not apparent to the engineer intent on studying the pictures of these members on the drawing board.

It will be noted that the President of the Phoenix Company declares the high unit-stresses adopted for the Quebec Bridge to be responsible for its failure. He says in effect that his company felt justified in proceeding with the work under these high unit-stresses, because of its faith in Mr. Cooper's judgment.

It is true that the engineers failed to attach due importance to the evidences of distress which the structure showed a month previous to its fall because the stresses it was carrying were so far below those for which it was designed. It is true, too, that at the present time no engineer will undertake to advocate or defend such high unit-stresses as were adopted at Quebec. We say advisedly "at Quebec"; for without doubt both the Consulting Engineer and the builders would have preferred to have worked with more moderate loadings. They were endeavoring to satisfy the demands of their clients for a practicable bridge at the least cost—endeavoring "to make a dollar earn the most interest." Of course, both parties had to accept responsibility for these high unit-stresses in undertaking the work. Undoubtedly both the Phoenix Co. and Mr. Cooper considered these stresses well inside the safety limit or they would have refused to undertake the work.

But the fact that the structure actually failed under a unit-stress which would be generally agreed to be a safe working load, shows that deficiencies in design of the failing members are to be placed ahead of the high unit-stresses as the chief cause of the disaster. As Mr. Szlapka says in his testimony: "There were no precedents for designing compression members of this magnitude. * * * * There is no reliable theory established, nor are there any results of extensive tests on compression members on record as regards detailing of these large members."

Attention should also be called to Mr. Szlapka's statement as to the need of remedying this lack of data. "It is the duty of the entire engineering profession," he says, "to secure numerous tests to establish rules to be followed in designing compression members of large size, in order to replace or to corroborate present opinions." This is closely in accord with the opinions expressed in these columns immediately following the disaster. Our report of the recent meeting of the National Advisory Board, on Testing Materials, elsewhere in this issue, indicates that the needs of the profession in this matter are likely soon to be met.

## LETTERS TO THE EDITOR.

### The Proper Load for a Burro.

Sir: In your issue of Nov. 7 I notice some correspondence on the proper load for a burro. In this connection Mexican practice in ore packing may be interesting.

Ore is commonly sacked so that the bundles may weigh 65 to 70 kg. (from 140 to 155 lbs.) each. Two of these bundles make a load for one burro. When the ore is very heavy or contains an unusually high percentage of moisture the bundles weigh more. I have frequently seen two sacks weighing 90 kg. (some 198 lbs.) each packed on one burro. The animals work under these loads from daylight until dark, day after day, month in and month out without any apparent ill effects. The trails are mostly down grade or level with occasional short and steep or longer and more gradual ascents. Every sack was weighed and the totals checked against carload weights at the smelter. While the above figures are from my own experience I know from observation taht they represent common practice over a large part of Mexico. The burros are those familiar to every inhabitant or traveler in Mexico or the southwestern part of the United States. I am not familiar with the South American burro which may be a smaller animal.

Yours truly,

Charles W. Comstock,
Consulting Engineer.

Boston Bldg., Denver, Colo., Nov. 12, 1907.

### The Gyratory System of Handling Street Traffic in Large Cities.

Sir: An editorial note in your issue of Nov. 14, 1907, calls attention to a contribution of Mr. Twelvetrees on the gyratory system of handling municipal traffic in large cities. While your editorial is an excellent one yet you do not bring out the point clearly that the two largest foreign cities, London and Paris, where it has been suggested to apply this system, do not contain any street car tracks in the central parts and scarcely any until you reach the outskirts of these cities.

This will eliminate your most serious objection to this system, as no car lines complicate matters in these places. Municipal traffic is at present carried on in Paris and London by underground railways, horse omnibuses, automobile omnibuses and cabs and in order to understand the advantages of the gyratory system as applied to these two places it will be necessary to explain a few of the local conditions.

PARIS.—This city is composed of many narrow streets emptying into wide boulevards. Pedestrians have no rights and no police protection and in consequence the speed obtained by automobiles and other vehicles is very high. Narrow refuge bays about three feet wide are located at nearly all of the crossings. The one rule that everyone obeys is to keep to the right. A typical place where the installation of this system would show marked results is at the intersection of the Place Vendome with the Avenue de l'Opera, where the present congested condition has become almost unbearable.

LONDON.—The traffic in this city, on account of its density, presents a most difficult problem. It is admirably handled at the intersection of the main streets by policemen, on the stop and start principle, letting a certain amount of traffic in one direction pass for a certain length of time, then holding that up and allowing a stream in the other direction to pass, yet the amount of traffic that can be passed at certain points during the day has about reached its limit. The intersection of the Strand with other streets offers a most excellent field for the installation of the gyratory system, for not only has London a very fine police force, but besides this it has courts that enforce the laws to such an extent that if a driver does not obey an officer he is arrested and fined every time and not let off with only a warning. In consequence of this, police and drivers work together to the benefit of both of them.

The main point in the gyratory system is to make the central circular space of such a diameter that the stream of traffic will be diverted well out from a straight line and there will be no possible chance or tendency to cut corners.

Apropos of entrances and exits to underground railroads located in the central circular spaces, the idea has already been taken advantage of in both London and Paris, and where it has not been possible to so locate them the companies have been forced to make an entrance through a house fronting on the str[illegible] at the desired point. In no case does one see, a[illegible] New York, the sidewalks blocked up by entrances [illegible] subway.

The situation in New York, complicated as [illegible] by so many street railway tracks, precludes the po[illegible]lity of installing the gyratory system at present [illegible] Mr. Twelvetrees' article does not suggest such an [illegible]stallation.

Yours truly,

Alfred C[illegible]me,

Office of Principal Assistant Engineer, Pen[illegible]lvania Railroad, Buffalo, N. Y., Nov. 18, 1907.

### An Objection to Model Tests.

Sir: Mr. J. F. Jackson of Houghton, Mich., [illegible]ggests in the Engineering News of Oct. 3, 1907, that [illegible]iniature columns be built of the same design and pr[illegible]rtions on a small scale, as those to be put into any s[illegible]cture, and tested for ultimate strength to reveal the[illegible] weaknesses before the large and costly members a[illegible] built and their weaknesses discovered by a possible f[illegible]ure.

I do not think this method of testing would afford a parallel case for comparison. Structures in [illegible]iniature are stronger in proportion to size than [illegible]ll-size structures of the same material. Witness [illegible] wire letter basket before me. Imagine a huge fab[illegible]cation five stories high, built of enormous crooked co[illegible]tinuous rods (if such could be obtained) and using this basket as a model. Would the structure stand? No one would think of attempting such a thing. Here is an ink bottle sitting upon a blotter. Suppose the blotter to be 1 ft. thick and of a proportional density. Now build upon this "foundation" a concrete monument of a size and shape similar to that of the bottle. How thick would the blotter be before the monolith was half completed? Yet the ink bottle makes no impression. Or take the case of house building with playing cards. A building several stories high can be built by a skillful person, yet no sane builder would attempt the feat upon a large scale. Large cards of the same material and proportions would fail by buckling and compression at the edges. They would not stand up under the weight. Numberless similar cases might be cited.

Imagine ourselves to be no larger than flies or ants. What enormous bridges we could build of wood and straw, or houses of paper, and use only a waterproof cement for holding the various parts together. And what an infinite amount of material we would have on hand for construction purposes. The cohesive forces we would have to deal with would be much different from those with which we are now familiar. They would be greatly magnified.

One might build a small bridge, of the Warren girder type, eighteen or twenty inches long, of splints of wood, glueing them together, and impose upon it a load which one would not dare to place in corresponding proportion upon a full-sized bridge of the same type and materials and of the best construction. And what glue could be used on a large bridge of this type of fifty or sixty feet span?

That there is a limit to stresses which may be employed in materials of construction is denied by no one. Just what that limit is we have determined in certain specific cases of simple assemblages. When we attempt larger structures we are at sea.

One may build miniature tunnels in damp sand without supports, but nothing but solid rock is safe when the same is attempted on a large scale.

In our large structures, it would seem, a different material must be used from that employed in the smaller structures. High tensile steel has been suggested. It is this and different alloys of steel which have made automobiles possible. And when the price of these materials has become such as to permit them to be employed in large quantities, a new era would be opened up in construction and building operations.

Yours very truly,

O. Burch.

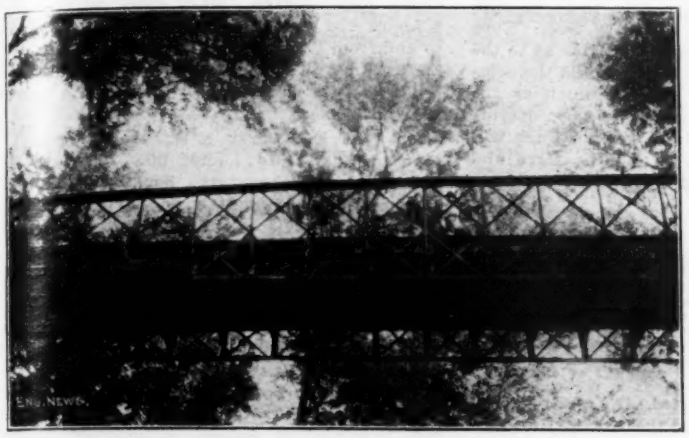
199 Forest St., St. Paul, Minn., Nov. 12, 1907.

[Most of the above comparisons depend on the fact that weight increases as the cube, area or strength as the square, of linear dimensions. This fact, however, has no bearing on the question of model testing against full-size testing. Model testing of structural members involves only this assumption: that similar structures are acted upon in similar manner by similar forces. This assumption says, in the case of a model test, that if the model is an exact copy of the large structure, forces similarly applied will produce the same kinds of distortion and will lead to the same type of rupture at the same proportional point of loading. The whole difficulty lies in reproducing the large structure in the model, as was very briefly suggested in a note appended to Mr. Jackson's letter.—Ed.

### A Remarkable Old Iron Bridge.

Sir: Some days ago the writer had the pleasure of examining an all-iron highway truss bridge which was built in 1850 and has been in continuous service since. This is such a remarkable record, especially as the design, in view of modern day practice, is very faulty, that a brief description of the structure will no doubt be of interest to many of your readers.

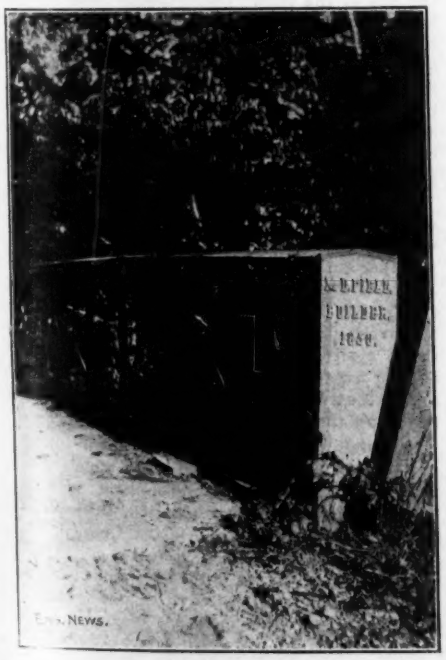
The bridge is 120 ft. long; 6 ft. deep at the ends and about 7 ft. deep at the middle. It more nearly resembles a double-intersection Whipple truss than any thing else. The top chord and posts are cast iron, the diagonal web



VIEW OF OLD HIGHWAY BRIDGE FROM BELOW.

members and bottom chord are wrought iron plates. All chord and web sections are the same throughout the length of the span and the only evidence given by the structure that its designer appreciated at all the actual distribution of stresses, is the slightly increasing depth toward the center. Two photographs are sent herewith, which show the general character of the structure. On the view showing the end post may be seen a heavy inclined strut. This is no part of the original structure. It is of timber (now completely rotted) and was put in by parties who raised the bridge some 20 years ago.

Practically all details are very faulty, as in no case which the writer noticed was the strength of a member developed at its connections. The bottom chord splices were particularly faulty as there were not one-third enough bolts to develop the strength of that part of the chord spliced. The cast iron web posts are very frail




An Iron Highway Bridge 57 Years Old.

affair with a slot in the middle through which the diagonals pass.

In roughly calculating the stresses to which the bridge must have been subjected, it is evident the wrought iron has been strained beyond its elastic limit, and that this in the case is borne out by the fact that there is a very decided sag in the bridge.

There are several facts in connection with the erection of the bridge which have aroused the writer's curiosity. Who was M. D. Field, the builder? Where was his place of business? The bridge is on the Nashville and Gallatin turnpike over Mansker Creek, separating Davidson and Sumner Counties in Tennessee. At the time it was built there was no railroad in operation in this part of the country and the material either came to Nashville by water or overland in wagons. The country traversed by the pike was then very sparsely settled and timber was plentiful and cheap. How was it, when iron bridge building was in its infancy (the first all-iron highway bridge built in the United States being erected in 1840) that such a structure was erected, no doubt at great cost, in such a remote locality? The only explanation to the last question is that at the head of control of this highway in 1850 must have been a progressive and adventurous man, who had no doubt traveled beyond the confines of his state and seeing the wonders others were working in iron had become impressed with its lasting qualities as compared with wood.

H. M. Jones.

Nashville, Tenn., Sept. 18, 1907.

[The bridge illustrated is certainly a remarkable curiosity; and the wonder is that a structure of such crude and defective design should have stood so long. It reminds one of the old story, which may be new to some of our readers, of the reply of Howe (the inventor of the Howe truss). He was acompanying a party of railway officials on an inspection tour over the road and liquid refreshments had flowed freely. The party got off to examine a bridge built after Howe's design which was in bad condition from exposure to the weather, and one of the number prodding the timbers with his cane struck a soft spot and thrust the cane half way through. "Look at this, Howe," said he. "What holds this —— bridge up anyway?" Howe looked at the questioner with lofty dignity and replied, "Principle, sir, principle!"

We know of no better explanation than this for the long life of the curious structure illustrated.

A second letter, received later from Mr. Jones, explains the mystery of the identity of Mr. M. D. Field:

Sir: Since writing the description of the Mansker Creek bridge I have found one of the oldest engineers in the community, and he gives the following information regarding Mr. Field: He was a brother of the celebrated Cyrus W. Field, and came to these parts originally as a contractor on the Nashville & Decatur R. R. He built the first suspension bridge across the Cumberland River at this point, which bridge was long since taken down. He also erected a number of other short-span bridges around here, but the Mansker Creek bridge is the only one yet left in service. I am informed that the material for these structures came up the Mississippi from New Orleans, and it was probably brought to the latter point from New York.

H. M. Jones.

Nashville, Tenn., Oct. 7, 1907.

We have verified some of the foregoing statements by consulting the genealogy of the Field family, compiled by Frederick C. Pierce for the late Marshall Field of Chicago. Some amplification of Mr. Jones' information may be of interest to our readers:

The builder was Mathew Dickinson Field, son of David Dudley Field, born at Haddam, Conn., on June 26, 1811. A brother of Cyrus W. Field, he was also a brother of David Dudley, Stephen J. and Henry M. Field—all men of national distinction. For many years he was a paper manufacturer at Lee, Mass.; in 1843 he moved to St. Louis, where for 11 years he was engaged as a contractor in railway and bridge building.

The genealogy states that the Nashville suspension bridge which he built—of 656-ft. span, 1,956-ft. total length including approaches, and 110 ft. above the water—was destroyed by the Confederates in 1863; that he also built a similar bridge over the Cumberland at Clarksville, Tenn., and, later, one at Frankfort, Ky., "of strength sufficient to bear the passage of railroad trains."

In 1854 Mr. Field returned to Southwick, Mass., and re-engaged in the manufacture of paper. He died on March 22, 1870.—Ed.]

### The Effect of Confined and Compressed Air on Exposed Sea Walls.

Sir: I have at various times heard the term "disintegration" used in connection with concrete sea walls and breakwaters, such as the Aberdeen breakwater in Scotland. There it was found that the enormous seas, in plunging against the surface of the breakwater in a perpendicular or sloping mass, acted as a mighty cutter or hammer and did cut out the concrete, and it was called disintegration. That was all that was heard about it in the press.

It is now twenty-nine years since I first began to have anything to do with Portland cement. During that time I have, as superintendent and inspector, had the supervision of sea walls, quays, basins and breakwaters. All these works were built with Portland cement concrete. According to the originator or him that discovered this process of monolith building, namely Sir Edmund Steel, the specification for a system of monolithic concrete called for a 1:2:3 for a mixture.

I have seen no improvement on that system. It will be apparent to all that the changes that have taken place when compared to the above, have had a deteriorating effect. Instead of a 1:2:3 mixture we have now 1:3:5 and sometimes up to 10. Wherever Sir Edmund's system has been adopted I have heard no complaint and did take note of the works that I built. These are today just the same as when built, without one flaw, and exposed to all the ocean elements. I often wondered how they stood the terrific shocks of the winter gales. I think it is too early to use the term "disintegration," as it seems a term more suitable to the infirmities of old age or bad work.

In my experience of building concrete under water, I have found that it cannot be done with crushed stone. Crushed stone falls away from the mass on to the wooden forms, leaving both the front and back faces one mass of pure stone with a very little mortar which just holds them in position and leaves a core or backbone of concrete along the center, no matter how the bucket or tube is used. In one large foundation the crushed stone was abandoned and river gravel used according to the following proportions: 3 parts coarse sand, 1½ of gravel. You see how near we were to Sir Edmund Steel's specification. The results were incomparable piers and quays with a face as if it were polished glass. No manipulation by hand could give the same result.

As a subaqueous inspector I have examined works under water built to these portions: 1 : 2½ : 5 and 1 : 2 : 4. In every case I found the work in a deplorable condition and could not account for how it stood on its feet, unless the water acted as a form to keep it standing. It ought to fall according to all known laws. Let those who are building sea and quay walls avoid crushed stone as they would avoid the mischief, and adopt gravel concrete to the proportions given; that is, up to low water or neap tide levels; then adopt Sir Edmund's specification 1:2:3. To reduce the cost from low-water level up to coping, use the crushed stone there with 35% of one-man stone rubble displacers. Then you have a conglomerate, a solid mass of monolithic concrete. Let the rubble displacers be kept back from the face of the form one foot and that solid foot of concrete be well rammed and faced up with a trowel.

I have found that in building these quays and sea walls that there was no disintegration, simply for the reason that the face was smooth as glass and as solid as concrete can be made. On building with 1:2:4, which seems to be generally adopted under water, I distinctly say it is utterly impossible to build with these proportions and at the same time use crushed stone. When building, the wall will be in the condition as described, full of holes under water that cannot be pointed, and the portion above water is always damp and will not hold the pointing. And it is called disintegration by some writers through chemical action; by others it is thought to be caused by ice abrasion, and they are nearer the mark than the chemical idea. What can be expected when great blocks of ice come smash on to a face of 1 : 2 : 4 concrete? It is not conceivable that 2 parts of sand will fill the voids of 4 parts of crushed stone. The half of the whole mass is full of air. A storm coming on from any direction of the seas is always worse between high and low water, as generally at high water the storm abates. The storm, being at its worst at the top portion of the underwater concrete and the bottom portion of the top concrete, it is there where the destruction begins. The top portion may be anything from 12 ft. to 20 ft. according to location. Just take that body of water 12 to 20 ft. backed up by the full weight and force of the ocean coming on with a rush just like a demon, and again receding back 100 ft. and coming on with crested waves from 20 to 30 to 50 ft. in height, with that snarled crested curve coming on and dashing on to the wall surface that has

holes and contains in its body a full half of air. This air is locked in and becomes compressed. That something has to go is certain. Explosions and a series of explosions take place. This goes on from day to day, week to week, month to month and maybe from year to year until it is discovered that the wall is getting cut up, and then it is called disintegration when it should be called air abrasion or compressed air explosions.

The remedy is as follows: For walls under water to any depth, use gravel concrete; use sea water; let the proportions be 4½ cu. ft. to one bag of cement; bring up your under-water concrete 2 ft. above low water level. Mark this particularly, as the density of your concrete depends on it. Use the full volume of water to one bag; if in dry, hot weather, 4 to 4½ ordinary pails of water, if damp, 3 to 3½. Do not be afraid to give the full volume of water, because when full it cannot receive any more if your concrete has not the full volume; then when you deposit it water is just like air. There can be no voids. It will rush in to fill that void and in its course rushing in it washes away the cement (which becomes free lime). Concrete is just like the hungry man. Give him a full meal, give him a good skin-full, and he cannot take any more. This volume of water is for density, solidity, and to produce a face such as no man by any manner of manipulation can produce. With no lodgement for air, your wall will stand for many generations and we will hear no more about disintegration. This building material will not be condemned for want of knowledge. Let the engineer look into these voids and compressed air explosions, and if not converted to this discovery, and still believes that it is a salt water and air chemical action, then hand the whole matter to the chemical expert.

O. FRASER,
Supt. and ex-Government Inspector of Works.
Port Colborne, Can., Nov 2, 1907.

## ANNUAL CONVENTIONS OF THE NATIONAL MUNICIPAL LEAGUE AND THE AMERICAN CIVIC ASSOCIATION.

The thirteenth annual meeting of the National Municipal League and the third annual meeting of the American Civic Association were held at Providence, R. I., on Nov. 19 to 22. A joint program was followed, but joint sessions were not always the rule. The Hon. Chas. J. Bonaparte, Attorney General of the United States, was reelected President of the League, and Mr. J. Horace McFarland, of Harrisburg, Pa., was reelected as President of the Civic Association. Mr. Clinton Rogers Woodruff was also reelected as Secretary of each organization. Among the many subjects presented before one or both associations were the preservation of Niagara Falls, municipal government by commission, home rule in municipal taxation, city planning, and municipal health work. Mr. Woodruff presented before each organization comprehensive reviews of work for municipal betterment during the past year.

### THE PRESERVATION OF NIAGARA FALLS.

The Civic Association devoted an evening to a three-cornered discussion of the relation of power development to the grandeur of Niagara Falls and the general attractiveness of the adjacent shores. Representatives of the power companies, of the New York and Canadian reservation commissions, and of the so-called McKim Commission and of the Civic Association were heard.

Gen. Francis V. Greene, Vice-President of the Ontario Power Co., whose talk was illustrated by lantern slides, maintained that accusations of greed and commercialism made against the men forming the development companies were largely unfounded. The 300,000 HP. now utilized, he said, is about one-tenth, and the 600,000 HP. which will probably be used eventually, is but one-fifth of the amount that could be effectively developed. Mr. H. H. MacRae, of the Electrical Development Co. of Toronto, and Mr. John L. Romer, for the Niagara Falls Hydraulic Power & Manufacturing Co., also spoke. All three of the speakers named in this paragraph conveyed the idea that their respective companies had not been neglectful of the scenic interests of the Falls. Mr. Romer stated that his company would expend a total of about $200,000 to satisfy "the taste of the public."

Mr. J. Horace McFarland reviewed the work done by the American Civic Association in behalf of the Falls, resulting, combined with efforts by others, in the Burton bill, under which the custody of the Falls was placed in the hands of Secretary Taft, and in the reduction, by the International Waterways Commission, of the amount of water that can be diverted from the Falls to 32,650 cu. ft. per sec., instead of 60,000—and this, too, under Federal control. The speaker commended the various power companies, save one, for the cooperative spirit in which they had met the efforts of the association.

Mr. John W. Langmuir, President of the Queen Victoria Niagara Falls Park Commission, said that besides the power companies now operating six others have authority to take water from Niagara Falls, or from Lake Erie, three on each side of the international boundary line. None of these companies is limited by charter as to the quantity of water it may divert. Should the companies, in the aggregate, take as much as the full requirement of the companies now operating "the scenic effect of the American Falls will be almost entirely destroyed and the force and grandeur of the Canadian Falls most seriously impaired."

He stated that

it is of vital importance that no further grants of water for commercial purposes should be made until it is definitely ascertained, from actual observation, what effect the full authorized withdrawals to power companies now in active operation will have on both American and Canadian falls. It is imperative that the franchises granted on both sides of the river should either be cancelled or restricted to the use of such volume of water as will not impair the beauty and grandeur of either fall.

Mr. Frederick Law Olmsted, Jr., of Brookline, Mass., described the work of the McKim Commission, of which he was a member. Many of the suggestions for decreasing the unsightly appearances of many of the surroundings of the Falls had been followed. The speaker thought that viewing the Falls both as a source of poetic emotion and as a source of mechanical power was incompatible. The esthetic value of the Falls should be put first and ought to be neither bartered or jeopardized until other water power facilities had been exhausted.

### MUNICIPAL TAXATION.

Nearly a whole session of the National Municipal League was devoted to a discussion of a variety of phases of municipal taxation. About twenty papers on this and allied subjects were scheduled, many of which, of course, were destined for the annual proceedings, only. Mr. Lawson Purdy, President of the Board of Taxes and Assessments, New York City, presented a committee report summarizing the responses from about a thousand letters of inquiry sent to all parts of the country. The consensus of opinion expressed was "that home rule in taxation is essential to the best development." The committee believed that "State and local taxation must be divorced in order to give" the cities home rule.

### RAILROADS AND MUNICIPAL BETTERMENT.

A paper before the Civic Association, prepared by Mr. Joseph T. Richards, Engineer of Maintenance of Way of the Pennsylvania Railroad, described the station and grounds improvement work done by that road. Mr. Geo. W. Wildin, Mechanical Superintendent of the New York, New Haven & Hartford R. R., read a paper on locomotives and the smoke nuisance. Four devices intended to prevent smoke are now being tested by that railway.

### FORCES MOLDING THE CITY OF THE FUTURE.

The two associations joined in listening to a number of papers dealing with various phases of this subject. Mr. Robert Watchorn, of New York City, urged that in the Young Men's Christian Association of the country there is a vast, well-organized force that needs only to be directed in order to do much effective work for city betterment. President Faunce, of Brown University, who took a helpful part throughout the joint conventions, spoke of educational influences, and noted in particular the vision of order and beauty that results from travel at home and abroad. Jefferson visited Athens and Rome and determined that Virginia should have an architectural object lesson in the way of university buildings. He personally superintended cutting the columns and capitals of the buildings.

Mr. Homer Folks, of New York City, ...ke of charitable and sociological work. The N... York Charity Organization Society, he said, h... decided to devote itself to the removal of the ...es of poverty. It has abandoned the theory ...t the individual is responsible for poverty. P...onary tuberculosis is one of the greatest caus... of poverty, and it is a preventable disease. ...e city must do the major part of this preventi... work, by improving housing conditions, and gi...g such transportation facilities, in speed and ci...pness, as will enable wage earners to live in ... relatively open country. Many could afford ... own a house and small garden if only they c...ld get to and from it in less than an hour and a ...lf.

Mr. Woodruff remarked that he had a l... of 45 municipalities now engaged in efforts to ...prove their city plan.

Mr. Geo. E. Kessler, a landscape arc...ect of Kansas City, Mo., told how Kansas City, at a time when its bonding limit had been reached, began the development of what is now a notable park and parkway system. Funds were raised by forming park improvement districts and levying assessments for betterments.

### MUNICIPAL GOVERNMENT PLANS.

Several experiments in municipal government have been initiated of late. Most of these have been based on the theory that the modern city is a business corporation and should be governed by a compact board of directors, instead of having a miniature federal government, with a higher and lower legislative body, an executive head, etc. The first example of the new ideas was Galveston, but it was the exigencies of the flood and not the desire to test a theory, that caused the establishment of a commission of five men to run all the affairs in that city. These five commissioners are now elected by popular vote. One is called mayor-commissioner and each of the other four commissioners is at the head of one of the four municipal departments, under which all the city activities are distributed. Dr. W. B. Munro, of Harvard University, who described the "Galveston Plan," said that on the whole it had been successful, at least as a temporary measure. In 1903, Houston adopted the plan and since then Ft. Worth, Austin and El Paso have taken it up. The speaker said that the use of the term "Commission" was unfortunate; that the Galveston commission differs in no essential respects from the the Selectmen who have governed New England towns, between town meetings, for two hundred years; that the Commission plan had the merit of centralizing responsibility and the defect of lessening the educative effect upon citizens that comes from the responsibilities of holding office.

A modification of the scheme that has become so popular in Texas is the "Des Moines Plan," which will soon go into effect in that Iowa city. A paper on this plan was sent by Mr. Silas B. Allen, of Des Moines. Under it, wards and various boards will be swept away, and the city will be governed and all its affairs administered by a single elected council, responsible for everything and to everybody—that is combining legislative and executive functions, and chosen by and representing the whole city.

In striking contrast to either of the plans just outlined is the "Newport Plan," which was enthusiastically described and upheld as a model by Rear Admiral F. T. Chadwick, U. S. N. Newport now has a Representative Council, elected for three years, in which is vested all legislative power, and a mayor and five aldermen, solely executive officers, elected for one year. The councillors and aldermen are elected by wards, and the mayor by the whole city. Admiral Chadwick considered the adoption of the Galveston Plan as a "step backward," both in its departure from representative government and in its merging of legislative and executive functions. He spoke strongly in favor of choosing executive officers for terms of ten years, instead of only for one year, as at Newport, and of choosing them for fitness, as German mayors are chosen. Only property-holders can vote in Rhode Island, and to vote for councilmen in Newport one must pay a tax on at least $134 a year.

## MUNICIPAL HEALTH AND SANITATION.

The conclusion of the two conventions was a long joint session, devoted to "Municipal Health and Sanitation." Dr. A. C. Abbott, Chief of the Bureau of Health of Philadelphia, and Professor of Hygiene in the University of Pennsylvania, presided. Dr. Abbott said the speakers had been selected with the object of presenting the best health protective work now being done. Rochester was represented by Dr. G. W. Goler, Health Officer of that city. Smoke abatement measures in Rochester were prefaced by popular lectures. With the increase in smoke that followed the coal strike the deaths from certain communicable diseases went up, but they fell as the volume of smoke was again reduced. The great problem of to-day is how to get the wage earner out of the crowded portions of the city.

Dr. Chas. V. Chapin, Superintendent of Health, Providence, R. I., said that when he assumed office, in 1884, municipal health work was directed almost wholly to municipal cleanliness. It is now known that dirt is not the source of disease. While cleanliness is important the health officer should not spend his time trying to make landlords clean pigstys and cesspools. Instead, he had better teach factory girls how to protect themselves against tuberculosis and teach doctors how to protect the public against typhoid-bacilli carriers. Dr. Chapin declared that there is a great need for a national bureau of health, to study questions for which the local health officer has no time.

Mr. M. N. Baker, President of the Board of Health of Montclair, N. J., described the organization and work of that board. From its creation, in 1894, the board has always had an engineer-member and it has also employed engineers as health officers. One of the most important lines of work in which the Montclair Board is engaged is its campaign for clean, safe milk. It now has set a bacterial limit of 100,000 and requires that all milk must be from cows free from tuberculosis, as determined by the tuberculin test.

Dr. C. O. Probst, Secretary of the Ohio State Board of Health, discussed "Municipal Sanitation and its Relation to State and National Governments." The history of typhoid fever in Philadelphia, Chicago, Cleveland, Cincinnati and other cities illustrates the fact that the suppression of that disease is not merely a local matter. Outsiders contract the disease and should be protected against it. There are but few instances where sewage purification plants are built for the benefit of those who stand the cost. Most of the advance in sanitary science has been due to the work of individuals or of a few states. The Federal Government should take up scientific health research for the benefit of the whole country. If every dollar spent for the Army and Navy were duplicated for national health work a great saving in life would be effected. Just as there are state agricultural experiment stations, so should there be state health experiment stations, and there should be a national health department worthy of the name. Its form, title and relation to the Cabinet is of little importance; the essential is a competent man as a head and such assistants as may be needed.

Dr. W. C. Woodward, Health Officer, Washington, D. C., read a paper dealing both with local conditions and with the relation of the general government to health problems. The negro population of Washington contributes disproportionately to the death rate, particularly to the mortality from bronchitis, pulmonary tuberculosis, diarrhea and enteritis. This seems to be due to race rather than environment, since narrow alleys have about the same total death rates as streets, but in alleys the death rate, white and colored, is as 1 to 2.15. The colored death rate has declined from 39.76 to 28.27 (years 1875-9 compared with 1900-4), and the white death rate from 19.35 to 15.93. There is great need of a system of accounts and statistics that would show the relation between appropriations for specific health work and the death and sick rate. Dr. Woodward then dwelt on the need of more public health work on the part of the general government, urging that the Federal Government should show as much interest in the life and health of the people as in minerals, forests, grasses, insects and animals. The Department of Agriculture, with its $9,450,000 a year for the study of soils, animals and plants, does much work in the interest of human health; the Treasury Department, through the Public Health and Marine-Hospital Service, does some, and some is done otherwise, as by the Census Bureau, in the collection of vital statistics. The national government should gather and organize the various workers on the skirmish line so their efforts could be centralized and their results checked and made generally available.

Dr. W. A. Evans, Commissioner of Health of Chicago, after outlining the varied and extensive work of his department, which embraces a sanitary supervision of water, milk, smoke, etc., also made a plea for more national health-protective work. The Agricultural Department spends large sums of money in studying soils, plants and animals because the farmers of the country have demanded it. It is high time that the fathers and mothers of the country demand that the government devote some of its income to the study of means to preserve the health and lengthen the life of their children.

During this session it was announced that the National Municipal League would create a committee of seven to study the correlation of municipal, state and national health work.

A resolution declaring that health-protective work ought to be entrusted to experts was adopted; also another resolution, introduced by Dr. Evans, in favor of taking the next national census, in cities of over 300,000 population, by city blocks, instead of by political subdivisions.

## CONVENTION OF THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS.

The 15th general meeting of the Society of Naval Architects and Marine Engineers was held in the Engineering Societies Building, New York City, on Nov. 21-22. The business sessions were very brief and the greater part of the time was devoted to papers and discussions. As the nature of these proceedings was necessarily very special and restricted largely to naval architecture, they have not seemed of wide enough interest to be fully treated in this article; therefore only a brief mention is appended of the subject and discussion of each paper.

(1) "An Experimental Investigation of Stream Lines Around Ships' Models," by Mr. D. W. Taylor, Naval Constructor, U. S. N. In this paper a method was developed of tracing the course of the water, parted at the bow, as it flowed about the hull of models. Some unexpected results were shown, as it was found that the greater part of the water parted by the bow passed under the vessel and came up again at the stern.

(2) "Some Experiments on the Effect of Longitudinal Distribution of Displacement Upon Resistance," by Professor Herbert C. Sadler. This paper described some experiments made in the experimental tank at the University of Michigan, on changes in longitudinal distribution of displacement and in shape of bow and stern on the resistance of the boat to passage through the water.

(3) "Further Tactical Considerations Involved in Warship Design," by Commander A. P. Niblack, U. S. Navy. In this short paper, Commander Niblack brought up to date a paper which was read twelve years ago. It was entirely devoted to a consideration of tactics, and especially as influenced by heterogeneous mechanical equipment and architecture in a fleet. In the discussion of this paper the destruction of prominent parts of battleships in the Russo-Japanese War was analyzed to show the behavior of modern warships under fire and to show advisable changes of upper-works design.

The use of gas engines was taken up in further discussion on the mechanical equipment of battleships.

(4) "Submarines of Battle-ship Speed," by Mr. Mason S. Chace. The author of this paper was formerly connected with the Japanese government in developing submarine boats, and this paper was a general consideration of the growth and probable development of submarine war vessels, especially in regard to speed and to those factors which fix the speed limits.

(5) "Motor Boats for Naval Service," by Naval Constructor L. S. Adams, U. S. N. The use of gasoline motor boats for auxiliary service in the navy was shown to be of enough importance so that it is given serious consideration by all line officers and naval constructors. Typical designs in use by the navy as tenders and for ferry service were shown. Along slightly similar lines were papers (6) and (7), on "High-Speed Motor Boats for Pleasure Use" (by Mr. Henry R. Sutphen), and "Some Observations on Motor-Propelled Vessels and Notes on the Bermuda Race" (by Mr. William B. Stearns), although, of course, the vessels described in papers (6) and (7) were necessarily outside of the navy.

(8) "The New Revenue Cutters for Special Purposes," by C. A. McAllister, Chief Engineer U. S. Revenue Cutter Service. The author of this paper gave the general dimensions and features of two notable vessels; one of these was for use along the Northern Pacific coast of the United States, where the hazards of wind, currents and fog are extreme and little known even by men who navigate these water constantly. Investigations on recent ship wrecks in this region have disclosed a loss of some 700 lives and of millions of dollars of property in the last century. This knowledge has caused a demand for a sea-going, life-saving vessel. The second vessel described is intended for exclusive use as a derelict destroyer in the North Atlantic Ocean. The craft was designed especially to keep the sea under all conditions, for a large radius of action, for considerable towing ability and with magazines suitable for carrying large quantities of high explosives.

(9) "Test on the Governor Cobb," by Professor W. S. Leland (Massachusetts Institute of Technology) and Mr. H. A. Everett. This paper was a memorandum of comparatively incomplete tests on the first turbine steamer built in the United States. The paper was severely criticized for its incompleteness and for the consequently somewhat misleading character of the data and statements presented. In the discussion it was maintained that it was not complete enough to fairly show the best performance of the "Governor Cobb" under good conditions. The authors, not being present, were invited to add to the paper at a later date.

(10) "Appliances for Manipulating Life Boats on Sea-Going Vessels," by Mr. Axel Welin. This paper showed the general defects of common davits and the mechanical superiority of the Welin Quadrant design.

(11) "The Transportation of Refrigerated Meat to Panama," by Mr. Roland Allwork. A description is given in this paper of the refrigerating plants installed in 1906 on five steamers of the Panama Railroad Steamship Line. Considerable detail was given of the piping and cooler systems employed and of the construction of the refrigerator rooms.

(12) "Two Instances of Unusual Repairs to Vessels," by Assistant Naval Constructor W. B. Ferguson, Jr., U. S. N. The first case treated was that of the extensive temporary and permanent repairs to the bottom of the collier "Nero" after grounding in August, 1906, off Block Island. The second case taken up concerned the renewing of sheathing and the replacing, with naval-brass fittings, the iron bolts and nuts holding planking and the main and bilge keels off Fire Island Lightship No. 68. The serious corrosion of the iron bolts on this vessel seemed to be the result of electrolysis, between the iron fastenings and the composition sheathing and spikes, in the presence of salt water which penetrated the wooden sheathing.

(13) "Wooden Sailing Ships," by Mr. B. B. Crowninshield. The designs and methods were broadly indicated in an interesting manner, beginning with Columbus' caravels, taking up such famous ships as "The Ark Royal" (Lord Howard's flagship of the cruise against the Spanish Armada), Drake's "Golden Hinde," the "Mayflower," the "Sovereign of the Seas" (Phineas

Petts' first large ship-of-war), the "Constitution," and the various merchantmen which have passed from the seas.

(14) "Some Early History Regarding the Double-Turreted Monitors, Miantonomoh and Class," by Mr. W. T. Powell. This paper, the final one on the programme of the convention, gives in general the results of a study of these vessels for range of stability. These results are reproduced in curves, which were stated to be the first complete ones of these vessels known.

These papers and discussions are contained in the proceedings of the society which may be obtained from the Secretary.

The present board of officers continues with little change. Rear-Admiral Francis T. Bowles, U. S. N. (Retired), President of the Fore River Ship Building Co., was re-elected President of the society, and Mr. W. J. Baxter, Naval Constructor, U. S. N., was re-elected Secretary-Treasurer. Mr. J. W. Miller, Vice-President of the New England Navigation Co., was elected Vice-President to fill the vacany caused by the death of Commodore C. H. Loring. Mr. J. R. Andrews, President of the Hyde Windlass Co., Bath, Me., was elected associate member of the Council to replace Mr. J. W. Miller. Mr. F. L. Du Bosque, Assistant Engineer, Floating Equipment, Pennsylvania R. R., was elected a member of the Council to succeed Captain W. H. Jaques.

## A NEW SPEED-VARIATION MECHANISM FOR POWER TRANSMISSION.

The accompanying photograph shows a working model of a recently-developed mechanism for transmitting power at variable speeds. Fundamentally the device is based upon the gear-and-cone principle, but the principle is applied in a novel way. The gear-cone shown is provided with 20 circumferential rows of "gear pits"; and parallel with the slant of the cone is a shaft on which is feathered a spur gear having pin teeth conoidal in form. This gear is adjustable longitudinally on its shaft so as to be brought into mesh with any desired row of gear pits on the cone, thereby causing the driven element, which may be either the gear or the cone, to rotate at a speed depending upon the ratio of the number of gear pits in that row to the number of teeth on the spur gear.

The rows of gear pits on the cone are so arranged that the center of one pit in each row lies in the same element of the cone. The pits in this row are formed in a sliding bar, movable in either direction a distance equal to the space between successive circular rows of pits. This movable bar is shown in the photograph, at the front.

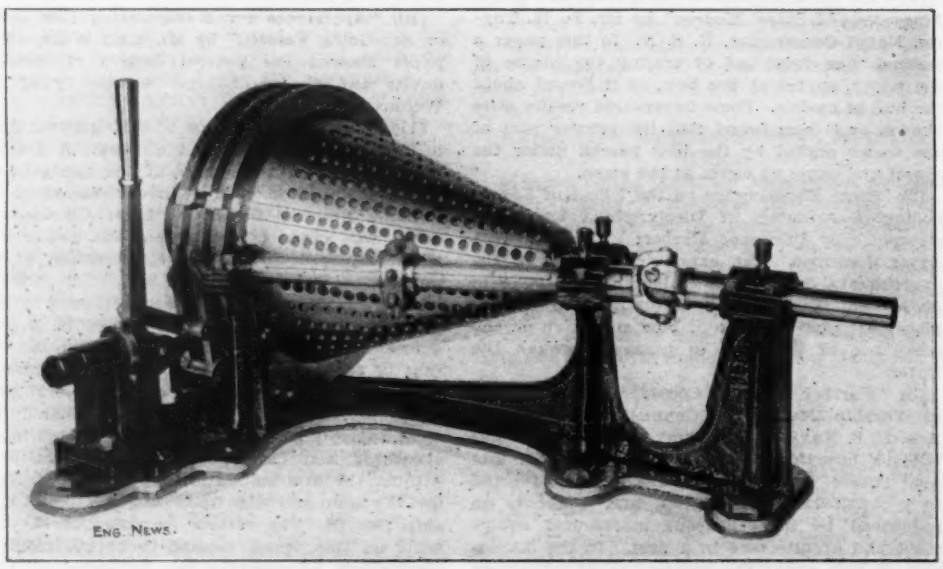
Mechanism is provided for shifting this slide in either direction at the instant in the cone's rotation when the slide is parallel with the shaft carrying the spur gear. Naturally, at that instant one of the teeth is in full mesh with a pit in the bar; and the movement of the bar carries the spur gear along its shaft, before the next tooth is in mesh, until it meshes with a pit in either adjacent circular row of pits.

In the model shown the shifting mechanism consists of two cams, actuated by the lever, either of which enters the corresponding groove at the base of the cone and throws the bar by means of a lug on the latter. The lever may be held in either operative position, each revolution of the cone then causing a shift of one row in the spur gear. The curved "ears" below the cams, one of which shows in the photograph, throw the slide back to its normal position after each shift.

To prevent the gear from running beyond the rows of pits at either end of the cone, mechanism is provided within the cone to throw the operating lever back to an inoperative position; the angular lug shown just above the right-hand cam is the external part of this safety provision. A spring throws the lever to its inoperative position when released by the hand at intermediate positions of the gear.

The pin teeth on the spur gear—the parts which will receive the most wear in service—are removable and renewable. In the model shown the pits are drilled straight, i. e., cylindrically, and the teeth are conoidal. The manufacturers state that they have developed machinery for cutting both the pits and the teeth on correct odontoidal principles.

The mechanism is the invention of Mr. G. L. Reenstierna, of Edgewater, N. J., and is being manufactured by the R.-W. Speed Variator Co., of New York City.*




WORKING MODEL OF THE R-W SPEED VARIATOR.

*820 Singer Building.

## A NEW SILENT DRIVE CHAIN.

A recent development in drive chains, differing from others in the field† in that the teeth are at the centers of the links instead of at the pins, is shown in the accompanying cuts.

Fig. 1 shows a bottom and side view of a section of the chain. The links are stamped from high-carbon steel, from 0.05 in. to 0.075 in. thick. The two end links in each row are retaining links only. The pins are not riveted, but have an annular groove at each end, as shown in the photograph. One hole in each retaining link is keyhole shaped, and in assembling the chain this end is put on first and down so as to lock the eat in the groove; this locks the adjacent retaining link, and so on through the chain. The retaining link at the coupling point is in two pieces, as shown in Fig. 2. The retaining links are much thinner than the driving links. The facility with which the chain may be taken apart, lengthened, will be evident. The faces under the pins are of a sufficient angle to clear the ners of the wheel teeth, adapting the chain to eels of any size. The pins are case-hardened, nd are of the same radius as the outer or bearin nds of the holes in the links, thus giving larg bearing surface and doing away with the exces wear

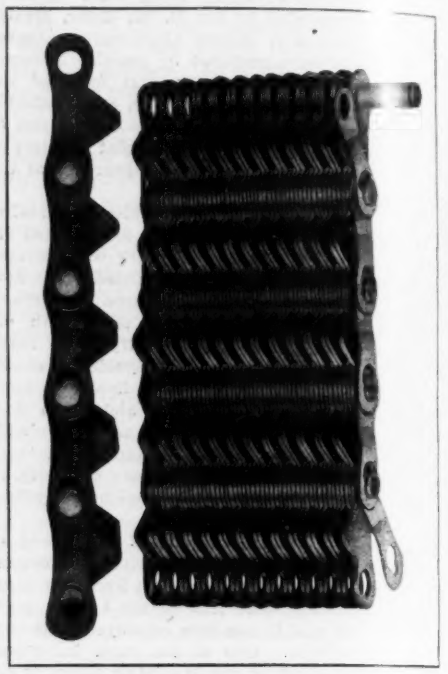


Fig. 1. Section of Schmidt Silent Drive Chain.

found where the holes are circular and larger than the pins.

When elongated by wear, the chain rides out on the wheel teeth as the pitch lengthens, as shown in Fig. 2. In entering or leaving the driving arc, the link teeth clear the wheel teeth, and undue wear from friction is avoided. High speed ratios are declared possible by the makers of the chain, who state that it will operate successfully at 20:1.

The chain is the invention of Mr. Carl G. A. Schmidt, Jr., and is manufactured by the Schmidt Drive Chain Co., of 265 Broadway, New York City. A chain installed in a large tannery at Newark, N. J., drives a rotary pump at 141 r. p. m. from a 5-HP. induction motor running at 1,130 r. p. m.—a reduction of 8.1.

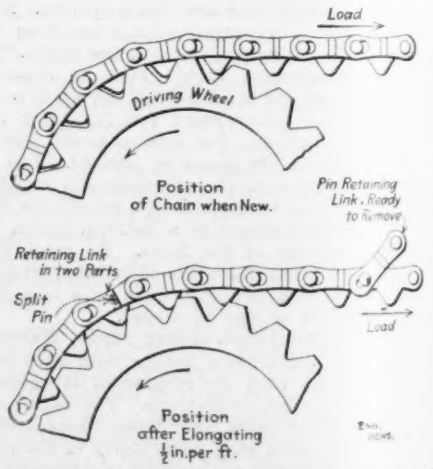



Fig. 2. Diagram Showing Automatic Adjustment of Schmidt Drive Chain when Lengthened by Wear.

THE CONSOLIDATION OF PITTSBURG AND ALLEgheny, Pa., provided for by an act of the Pennsylvania Legislature, has been upheld by the U. S. Supreme Court. The consolidation, presumably, will go into effect at once. The present city officials of Allegheny will, until the election of 1900, become deputies to the officials of Pittsburg.

†A description of the well-known Renold chain will be found on p. 154 of Engineering News for Sept. 5, 1901.

## A DRAINAGE SYSTEM NEAR EAST ST. LOUIS, ILL.

By WILFORD A. THOMPSON,* Assoc. M. Am. Soc. C. E.

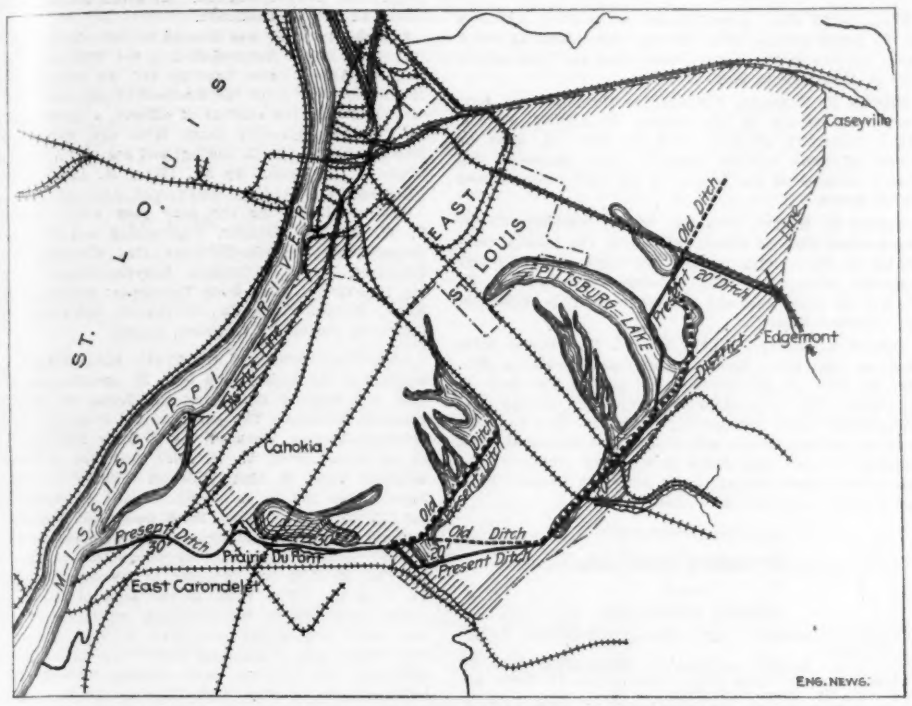
A contract has just been let to R. A. Brown, of Vincennes, Ind., at 16½ cts. per cu. yd., for dredging about sixteen miles of drainage canals. The district in which these canals are to be constructed lies east and south of East St. Louis, Ill., a part of what is called the American Bottoms, lying between the bluffs on the east and the Mississippi on the west.

In 1892 a ditch (10 or 12 ft. bottom width, no record on file) was dug, as shown on the accompanying map. This ditch has filled up from dirt washed down or brought in by the high water from the river so that only in a few places can any trace of the old ditch be found.

In 1892 the high water backed in and filled the lakes as shown. The water slowly evaporated until the summer of 1902 these lakes were almost dry except in a few places along the bluffs. In that part of Pittsburg Lake near East St. Louis some subdivisions were laid out and several houses were built. The high water of 1903 again filled these lakes. At present there are some places in Pittsburg Lake where the water is 10 ft. deep.

Where the Louisville & Nashville R. R. enters the bluffs is a creek which after heavy rains floods the tract between the railway and the northern limits of the district.

To take this creek and to drain the lakes the present system of ditches was designed. The engineer's estimate calls for the moving of about 1,000,000 cu. yds. of dirt, about half of which will be used for levee purposes. Mr. W. J. Crocken is engineer for the drainage work.




MAP SHOWING DRAINAGE WORK UNDER CONTRACT NEAR EAST ST. LOUIS, ILL.

## MUNICIPAL DATA AND STATISTICS.†

The measure of success of each of the many departments of municipal life can be determined by complete and properly arranged data and statistics of each department. These statistics should include hundreds of details beside dollars, because it is not by money cost, although that is important, that the true success of municipal administration is measured.

Municipal statistics are too often kept in an obscure manner, without analysis and without tables of comparison with the statistics of previous years. They should be properly analyzed into many subdivisions or units. Final condensed tables should set forth each year not only the statistics for that year but should be compelled by law or municipal ordinance to include the condensed statistical results of at least the preceding four years. Such complete statistics not only enable an administration of a department to show what it has accomplished and indicate the results compared with previous administrations, but they are also of indispensable assistance in making up proper annual budgets for each succeeding year.

Much has been said and written upon the uniformity of muncipal statistics in different cities. While uniformity is important, it is far more important that statistics should be properly analyzed and complete, whether they are kept in just the same manner as other cities or not.

There is no more important a department or bureau for a city to establish than that of municipal statistics. The chief in charge of that bureau should be a man of the highest character and education possible to obtain. Nothing will help more to solve the trying problems of our city administrations than municipal statistics. They help a city avoid the mistakes and reap the benefit of its own progress and that of other cities, under a system of exchange and comparison with the records and data of other cities. The principal cities of Europe have maintained and exchanged such valuable data for many years and a few American cities have started to do the same.

We recommend that the members of this society endeavor more and more to record and have published the statistics of their departments and we urge all municipal departments to do the same. We recommend that every city establish a bureau of municipal statistics or a municipal statistician and prescribe the detailed records which must be kept; also how and when these services shall be performed and reports rendered for the information, guidance, assistance and benefit of living and future inhabitants.

* Assistant Engineer, East St. Louis, Ill.

† Condensation of a Report made to the American Society of Municipal Improvements, Detroit, October, 1907, by the Committee on Municipal Data and Statistics, consisting of J. W. Howard, Chairman, New York City; H. W. [illegible], New York City, and William Fortune, Indianapolis.

THE WORST RAILWAY WRECK OF THE WEEK is reported in a press despatch from Barcelona, Spain, dated Nov. 25. An express train bound from Barcelona to Valencia was crossing a bridge near Tarragona, when the bridge collapsed and all but three cars went into the river. Sixteen bodies were taken from the wreck, it is said, and 30 persons were injured.

Three persons were killed on the Philadelphia & Reading Ry. at Philadelphia, on Nov. 26, in a rear-end collision between a coal train and a freight train. Mistaken signals is the reported cause.

A head-on collision occurred between two passenger trains on the Vandalia R. R. on Nov. 19, at Vevay Park, Ill. One person (an engineer) was killed, and four injured. Dense fog caused the wreck.

In a head-on collision on the Wheeling & Lake Erie R. R., on Nov. 18, between a freight train and a light engine, one person was killed, and two fatally and two seriously injured. Fog is also the reported cause of this wreck.

AN EXPLOSION of four boilers on Nov. 20 in a mill of the John L. Roper Lumber Co., near Norfolk, Va., killed six men and injured one fatally, and a dozen others more or less seriously.

An explosion reported in a press despatch from Kenora, Ont., on the same date, killed seven men and injured four at the eastern construction works of the Grand Trunk Pacific Ry. at Dryden. The nature of the explosion is not stated.

THE "MAURETANIA" encountered uncommonly severe weather on her maiden voyage, with the result that her time for the 2,781 miles from Daunt's Rock to Sandy Hook was considerably longer than the "Lusitania's" previous record. The total time was 5 days, 5 hrs., 10 min.—making an average speed of only 22.21 knots per hour; but she lowered the world's record for daily runs, by steaming 624 miles for the 25 hours ending at noon on Nov. 20—6 miles better than the record made by the "Lusitania" on her last western voyage. The "Mauretania's" average hourly rate for that day's run was practically 25 knots per hour.

ALEXANDER GRAHAM BELL'S AIRSHIP was launched at Baddick, N. S., on Nov. 10, from the inventor's laboratory. The airship, which seems from descriptions to be more of a kite than an airship, was taken out on Bras d'Or Lake, but owing to the weather no flight was attempted. The following description of the invention is quoted from current press notices:

> The ship, or kite, in itself a section of a tetrahedron, is 13 meters long on top, 10 meters along the bottom, by 3 meters deep. It is composed of 3,393 units, or small tetrahedrons, two faces of which are covered with silk, this forming a two-winged cell. These cells are arranged to give, as the result of many tests, the maximum stability with the lightest weight. A hole has been cut through the center of the contrivance to furnish accommodation for the motor and a navigator. The ship is also provided with a bow for flying purposes. Three floats are used as a part of its construction to support it while on the lake. A motor with four cylinders of 20 HP. will drive two solid screw propellers on the same shaft, but in opposite directions. With the motor in position the airship weighs 220 lbs.

THE PRODUCTION OF COKE in Great Britain during 1906 is shown in the "General Report on Mines and Quarries," for that year, just issued. The total coke production was stated as 19,296,526 tons, worth about $62,246,000. The year before the production was 18,037,985 tons valued at $53,129,000. This includes blast furnace and gas works coke; 29,798 ovens were reported in operation in 1906 and in 1905 the figure was given as 31,060. For these two years the number of bee-hive ovens in use is given as 23,454 and 25,514 respectively. It is seen that a decrease in the number of ovens in use has been accompanied by an increase in production. At 51 out of 257 works by-products were recovered. In the United Kingdom 1,399,542 tons of coal (steam, household, coking and mixed) were made into 1,513,220 tons of fuel briquettes having a value of about $4,495,230. These figures for 1905 were respectively 1,109,797 tons, 1,219,586 tons and $3,588,355.

THE RICHEST GOLD MINE IN THE WORLD, according to a tabulation of the world's large gold mines recently made by the "Mining and Scientific Press," of San Francisco, is the Robinson mine at Johannesburg, S. A. The capital of the Robinson Gold Mining Co., Ltd., is £2,750,000 ($13,350,000). Milling operations were begun in January, 1888, since which time there have been 3,212,200 tons of ore mined altogether and 2,686,300 tons milled. The total working expenses have been £3,552,300 (about $17,250,000) or 26s. 5.4d. (6.43) per ton.

The total amount of gold produced has been 2,253,800 oz. fine, valued at £9,474,700 (about $46,000,000) or 70s. 6.5d. ($17.11) per ton. The working profit has been £5,922,400 (about $28,750,000) or 44s. 1.1d. ($10.72) per ton. It is estimated that the Robinson mine will have ceased to be profitable by the end of 1920, at the end of which time it is estimated that it will have yielded a net profit of 70,000,000 tons.

A LARGE, STEAM-DRIVEN MOTOR TRUCK for shipbuilders' use, designed to carry steel plates up to 40 ft. long (the size used on the last two Cunard line giants), was recently built by the Mann Patent Steam Cart & Wagon Co., of Hunslet, England, for use at the yards of Swan, Hunter & Wigham-Richardson at Wallsend-on-Tyne. The truck, described in the "Iron & Coal Trades Review" of Oct. 4, was built low so as to allow passage beneath the hull of a vessel on the ways, and consequently the motive power and source had to be mounted low. The boiler is carried forward, with a funnel at each side, and is provided with a damper to direct the exhaust gases into either funnel. The driver sits beneath the load, directly behind the boiler, and may steer from either side; just behind his seat is a water tank, and the engine is geared to the rear axle and runs in an oil bath.

IMPACT TESTS ON RAILWAY BRIDGES are being made under the direction of the Committee on Iron and Steel Structures of the American Railway Engineering and Maintenance of Way Association. The expenses are defrayed from a fund provided by subscriptions from railway companies, and about $5,530 has already been sub-

scribed, which is sufficient for about two seasons. The work is in charge of Prof. F. E. Turneaure (University of Wisconsin), whose instrument designed for this work was described in Engineering News, June 20, 1907, p. 681. In a progress report published in Bulletin No. 92 (October) of the above Association, it is shown that tests have been made on a number of pin-connected and plate-girder bridges on five different railways. The longest span tested was 225 ft. The other bridges ranged from 120 to 160 ft. for the pin-connected structures, and from 25 to 80 ft. for the plate-girder structures. In each case special trains were furnished, consisting of a locomotive and, usually, loaded cars sufficient in number to cover the structure. These special trains were run over the bridges at various rates of speed, ranging from very slow to the maximum practicable speed. Some observations were made on trains in the regular traffic. Nearly 600 observations were obtained from a deflection instrument and from eight extensometers attached to various members.

## PERSONALS.

Mr. Mortimer A. Sears, M. Am. Inst. M. E., has opened an office for consulting mining engineering at 43 Broadway, New York City.

Mr. Thomas McCaffery, Assistant Superintendent of the Los Angeles division, Southern Pacific Ry., is reported to have resigned.

Dr. H. M. Payne has been elected Dean of the recently-created Department of Mining Engineering at the University of West Virginia.

Mr. J. K. Gray has resigned as Superintendent of the Western Ohio Electric Ry., and will become Manager of the Mansfield line of the Cleveland Southwestern Ry.

Mr. W. T. Dorrance has been appointed Designing Engineer for the Exterior Zone of the New York Central & Hudson River R. R., with office at the Grand Central Station, New York City.

Mr. C. M. Shank has resigned as Superintendent of the Lemont (Pa.) plant of the H. C. Frick Coke Co., and is succeeded by Mr. Burton Boyd, formerly superintendent of the Continental No. 2 plant.

Mr. E. S. Moore, recently in charge of exploration work in northern Ontario for the Ontario Department of Mines, has been appointed Fellow in the Department of Geology in the University of Chicago.

Mr. Geo. A. Gallinger, of the Chicago office of the Independent Pneumatic Tool Co., has been appointed Manager of the Pittsburg office to succeed the late Mr. Richard D. Hurley, who died on Nov. 5.

Mr. J. P. Spivey has been appointed Superintendent of transportation of the Kansas City Southern Ry., succeeding Mr. F. S. Rawlins, resigned. Mr. Spivey was Chief Clerk to Mr. Rawlins prior to his resignation.

Mr. Glenn D. Holmes, Assoc. M. Am. Soc. C. E., formerly Engineer of Water Supply on the New York Barge Canal at Syracuse, has been appointed Chief Engineer of the Syracuse Intercepting Sewer Commission.

Mr. Wm. S. Gorsuch, of the electrical engineering department of the New York Central & Hudson River R. R., has been appointed by the Y. M. C. A. of New York City to conduct its evening course in electrical engineering.

Mr. E. E. Johnson, Assistant Superintendent of the International & Great Northern R. R. at Mart, Texas, has been appointed Superintendent, succeeding Mr. C. J. Larimer, resigned. Mr. Johnson is succeeded by J. D. Whittington.

Mr. H. W. Peck, Assoc. Am. Inst. E. E., Electrical Engineer, with the Consolidated Gas, Electric Light & Power Co., of Baltimore, has accepted a position as Assistant Electrical Engineer of the Rochester Ry. & Light Co., of Rochester, N. Y.

Mr. Geo. K. Lowell, General Manager of the Detroit, Toledo & Ironton Ry. and the Ann Arbor R. R., has been elected Vice-President of the two companies. Mr. Lowell began his railway career as a roundhouse employee on the Boston & Maine R. R.

Mr. Wm. S. Love, who for eight years managed the business of the Wheeler Condenser & Engineering Co. in the central West, and who has been in New York City for the last year as General Sales Manager, will resume charge of the Chicago office of the company on Jan. 1.

Mr. J. N. Galbraith has been appointed Chief Engineer of the Mexican Central Ry., succeeding Mr. L. Kingman. Mr. C. T. Norton has been appointed Superintendent of the Coahuila & Pacific division, succeeding Mr. E. R. Walters. Mr. Galbraith's headquarters will be at Mexico City and Mr. Norton's at Saltillo.

Mr. W. E. Whitney, Superintendent of the Union Station at Denver, has been made Superintendent of a newly-created division embodying the Union Pacific Ry.'s line from Rawlins, Wyo., to Green River, Wyo. (heretofore part of the Wyoming division) and the Oregon Short Line R. R.'s line from Green River to Ogden, Utah. Mr. Whitney will be stationed at Ogden.

Mr. Foster Crowell, M. Am. Soc. C. E., a consulting civil engineer of 18 Broadway, New York City, has been appointed Commissioner of Street Cleaning for New York City, to succeed Dr. Walter Bensel. Dr. Bensel had held the office only temporarily, for 4½ months, after the resignation of Commissioner Craven.

Mr. A. L. Hertzberg, Engineer of Maintenance of Way of the Canadian Pacific Ry., has been appointed Division Engineer of the Ontario division with office at Toronto. Mr. J. M. R. Fairbairn, whom he succeeds, has been made Division Engineer at Montreal. The position of Engineer of Maintenance of Way has been abolished and its duties included with those of the Assistant Chief Engineer, Mr. F. P. Gutelius.

### Obituary.

Prof. Asaph Hall, a well-known astronomer, who was in the naval service from 1863 to 1891—including many years' service in the Naval Observatory at Washington—died at Annapolis on Nov. 22.

Charles S. Magowan, Professor of Municipal and Sanitary Engineering in the College of Applied Science, State University of Iowa, died on Nov. 14, after an illness of some months duration. Prof. Magowan had been a member of the faculty of the University of Iowa for 21 years.

Samuel C. Walker, President of the Harbison-Walker Refractories Co., of Pittsburg, one of the largest companies in the country making fire brick and refractory materials, died at Shields, Pa.—his home—on Nov. 23. He was 59 years old, and a brother of John Walker of the Carnegie Steel Co.

Edward A. Handy, M. Am. Soc. C. E., General Manager of the Lake Shore & Michigan Southern Ry., died on Nov. 21 at Chicago. Mr. Handy was born at Barnstable, Mass., in 1855; he entered the railway field immediately after graduation from the Massachusetts Institute of Technology, and in 1888 was appointed Chief Engineer of the Lake Shore & Michigan Southern Ry., and later General Manager. He was also General Manager of the Lake Erie & Western R. R.

## ENGINEERING SOCIETIES.

### COMING MEETINGS.

AMERICAN SOCIETY OF REFRIGERATING ENGINEERS.
Dec. 2-3. Annual meeting at Engineering Societies Building, New York City. Secy., Wm. H. Ross, 154 Nassau St., New York City.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.
Dec. 3-6. Fifty-fourth annual meeting at New York City. Secy., Calvin W. Rice, 29 West 39th St., New York City.

SOCIETY FOR THE PROMOTION OF INDUSTRIAL EDUCATION.
Dec. 5-7. Convention at Chicago. Secy., C. R. Richards, Columbia University, New York City.

ASSOCIATION OF TRANSPORTATION AND CAR-ACCOUNTING OFFICERS.
Dec. 10. Annual winter meeting at Chicago. Secy., G. P. Conard, 24 Park Place, New York City.

AMERICAN ECONOMIC ASSOCIATION.
Dec. 28-31. Twentieth annual meeting at Madison, Wis. Secy., Winthrop M. Daniels, Princeton, N. J.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.
Dec. 30-Jan. 4. Annual meeting at University of Chicago. Secy., L. O. Howard, Cosmos Club, Washington, D. C.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
Jan. 15. Annual meeting at New York City. Secy., Chas. Warren Hunt, 220 West 57th St., New York City.

NATIONAL ASSOCIATION OF CEMENT USERS.
Jan. 20-25. Fourth annual convention at Buffalo. Secy., W. W. Curtis, 585 Caxton Bldg., Chicago. Convention Manager, Dal H. Lewis, 760 Main St., Buffalo.

NEW YORK ELECTRICAL SOCIETY.—At a meeting held Nov. 20, Dr. Lee De Forest gave an informal talk on "Wireless Telephony." The rudiments of wireless telephony, its similarity and dissimilarity to wireless telegraphy, the means of sending out undamped waves of extremely high frequency, the methods of breaking these up for the transmission of speech, the receiving apparatus, the use of wireless telephony in the navy, and the possible developments of the future were among the phases discussed.

MAINTENANCE-OF-WAY MASTER PAINTERS' ASSOCIATION.—The fourth annual meeting was held at Chicago, Nov. 19 and 20. Two or three papers dealt with the painting of steel railway bridges, and it was the general opinion that there should be no shop coat of paint. The sand-blast was not considered generally applicable for cleaning bridge work; chisels and wire brushes are most generally used. A paper on "Paint Stock" recommended that standard paints should be sent out ready mixed and of the proper colors. A paint car with ample supply of materials and tools is an economical addition to the equipment. Another paper discussed the problem of "Linseed Oil." Officers were elected as follows: President, A. B. Phelps (L. S. & M. S. Ry.); Vice-Presidents, W. I. French (N. Y., O. & W. Ry.) and M. F. Ebel (C., H. & D. Ry.); Secretary, H. J. Schnell, 100 William St., New York.

OHIO SOCIETY OF MECHANICAL, ELECTRICAL AND STEAM ENGINEERS.—The annual meeting was held at the Hotel Hollenden, Cleveland, on Friday and Saturday, Nov. 15 and 16. After the business of the society on Friday morning, Mr. W. L. Morris presented a paper on "Some Suggestions Concerning Management of Engineering Societies," and Mr. G. Jacobs, "Coil Insulation in Electrical Apparatus." The afternoon was devoted to a visit to the plant of the Sherwin-Williams Co., paint and varnish manufacturers. Friday evening, Prof. Wm. T. Magruder, the retiring President, delivered an address, "Some Suggestions on Industrial Education in Ohio"; Mr. W. A. Rowe presented "Air Washing and Humidifying, and Some of Its Industrial Applications"; Mr. B. F. Houghton, "Power, Heat and Light from Central Stations," on which Mr. A. L. Allen presented written discussion.

Saturday morning was devoted to visits to the plants of the White Steam Automobile Co., the Warner & Swasey Co., the Allyne Brass Foundry and the Brown Hoisting Machinery Co. After the business of the afternoon session, including the election of officers, a paper was read on "The Incandescent Lamp from the Manufacturer's Standpoint," by Mr. G. Loring; and one on "A Volumetric Study of Cast Iron," by Mr. Henry M. Lane, Editor of "Castings."

Officers elected for the next year were: President, F. W. Ballard, Manager, Engineering and Construction Department, Sherwin-Williams Co., Cleveland; Vice-President, W. C. McCracken, Superintendent, Engineering Department, Ohio State University; Secretary, W. A. Rowe, Buffalo Forge Co., Cleveland; Treasurer, Mason Chilcoote, Consulting Engineer, Akron.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—At a meeting of the society held Nov. 20, considerable discussion was aroused concerning the design of reinforced-concrete columns. The paper of the evening, "The Reinforced-Concrete Work of the McGraw Building," read by its author, Prof. W. H. Burr, described in detail the columns used in that building. These columns, in some places 180 ft. in length, consist of regular built up latticed steel sections, filled inside and covered outside for a thickness of two inches, with concrete. The largest columns have exterior dimensions at the basement of 29 × 29 ins. reducing at the eleventh story to 14 × 14 ins. The ratio of the area of steel section varied from 10% at the basement, where the steel carries about 57% of the total load, to 3½% in the ninth floor where 30% of the total load is carried by the steel. Although the column unit stresses allowed by the building code of New York were at the time this design was submitted, 350 lbs. per sq. in., the department allowed in this case 750 lbs. per sq. in. on account of the hooped column action which the enclosing steel angles and lacing are supposed to induce. These columns were built in two-story sections, 25 ft. in length, and poured in a similar manner to other concrete columns.

Prof. Burr, in the course of his address, advocated this type of column for all reinforced-concrete work, saying that it was the only absolutely safe design unless a large section of concrete was used with small rods to prevent undue surface cracking. Although some few tests have been made on similar columns, there is very little available information as to the exact stresses which can safely be put upon such members. Still, Prof. Burr thought that 750 lbs. per sq. in. was a very conservative load to put upon the concrete, provided, as in this case, the steel is designed to take the dead load.

The design of these columns was attacked by many members, principally upon two grounds, first, that they are decidedly uneconomical and second, that the conditions of design and construction are such as to preclude the close connection of concrete and steel which are necessary before the two materials can act as a composite body. Under the first objection, a member gave figures showing that a greater part of the steel could have been left out and there still would have remained a safe column. The writer, however, admitted that the column as designed was entirely different from the stock reinforced-concrete column and therefore too strenuous criticism should be reserved until tests had been made. The larger part of the criticism hinged on the probability that the concrete in being deposited down so great a hole as is left in the steel latticed columns would shrink to such an extent that the connection would not ensure a simultaneous working of the two materials.

Some general criticism of the whole building was indulged in on the grounds that for so tall a structure (11 stories) a skeleton steel construction had many advantages over the concrete design here used. The steel building would only require 80% more steel than is used in the design built and it is certain that the concrete would cost more than the fireproofing needed in a skeleton system. In addition, the concrete columns take up much more room than would the steel. Lastly, the steel building has just as low a fire insurance rate as the concrete.

Prof. Burr reserved his answers to the criticisms for a future written reply.

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